The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVIII No. 11 NOVEMBER, 1957

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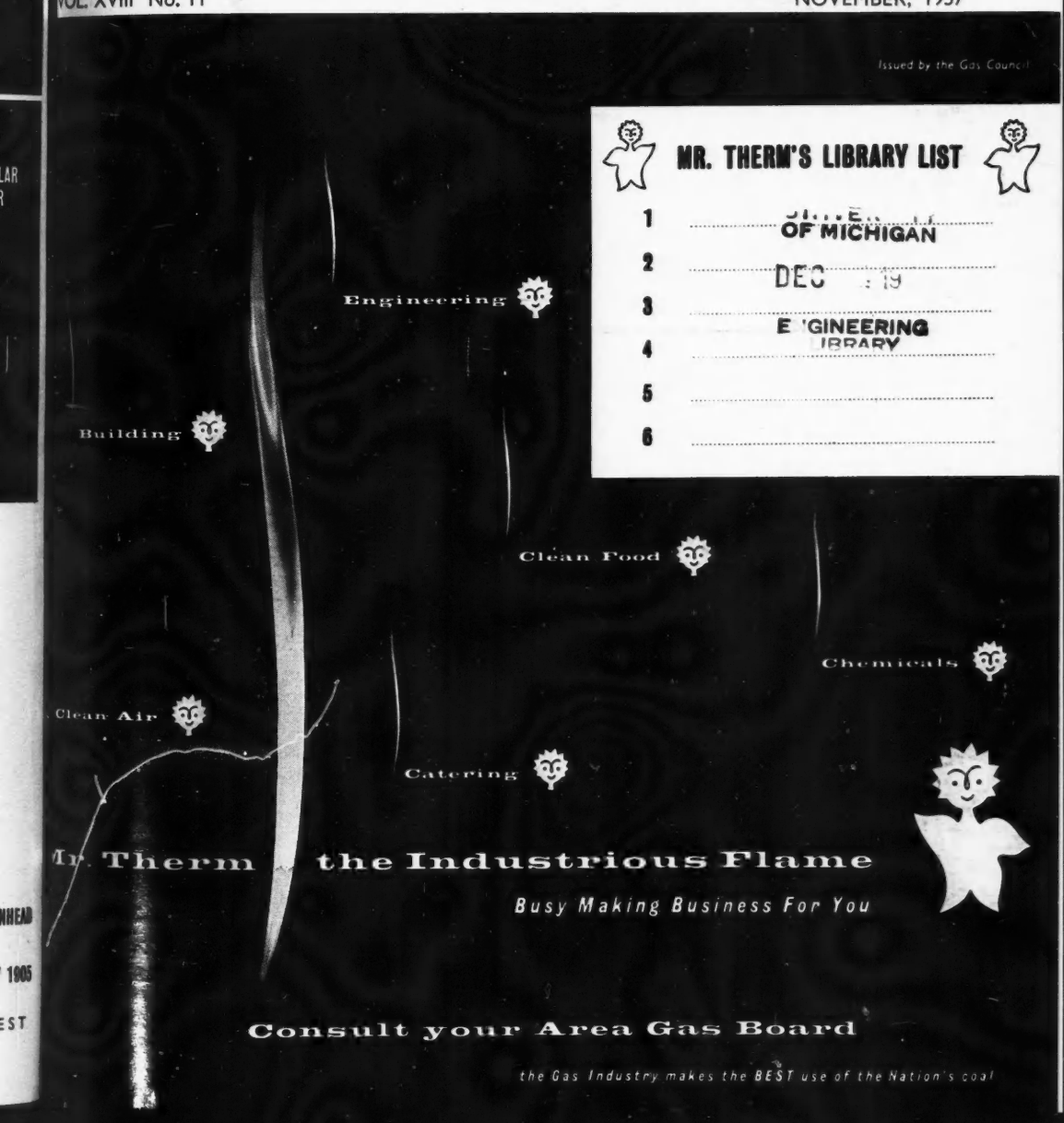

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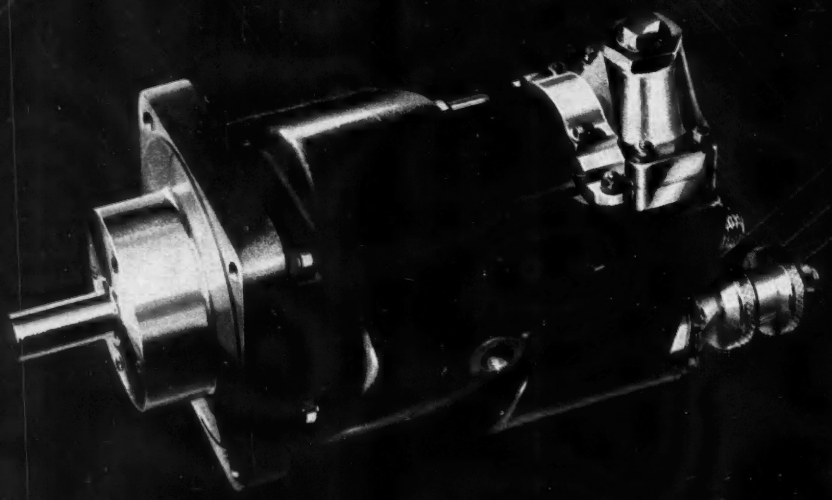

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

• *CARBIDE-COATED TOOLS AND WORKPIECES*

A method has been developed for the deposition of high-melting carbides on tools and workpieces without incurring the danger of damaging the base material by excessive temperature. For the production of deposits of titanium carbide, vanadium carbide, and tungsten carbide, use is made of gas mixtures which contain hydrogen, a halide of the carbide-forming metal, and a certain amount of volatile hydrocarbons. It is claimed that with the aid of this process it is possible to produce titanium carbide coatings which, when applied to a smooth metal surface, are distinguished by very slight surface roughness and an extremely fine-grained compact structure. The coatings are deposited practically uniformly, so that they reproduce the surface, including its irregularities. When the titanium carbide coatings are to be used for the surface protection of tools, workpieces, or machine parts which are predominantly subject to mechanical wear, especially sliding friction, it is recommended that the surfaces to be made wear-resistant be machined very accurately. Titanium carbide coatings are then obtained with a surface roughness of about 80 micro-inches. This roughness can be reduced to considerably below 40 micro-inches by polishing, e.g., with diamond dust, boron carbide powder, or with graphite powder produced by a cutting process. Where machine parts and tools with a rough surface are concerned, as for example, files and rasps, the surface of the base material is first brought to final shape and the carbide coating then applied. Generally, the process temperatures involved lie between 960 and 1000°C.

• *PRESSURE-SENSITIVE CELLS WITH INTERMETALLIC RESINS*

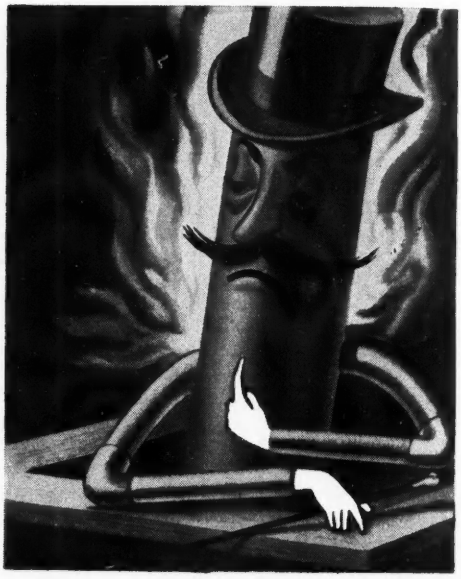
A recent report states that the introduction of pressure-sensitive cells made with intermetallic resins provides a versatile technique for measuring and controlling forces and pressures. The method is based on the variation in electrical conductivity with pressure exhibited by intermetallic resins, which are produced by processing rare earths with zirconium tetrachloride and are manufactured in the form of plastic wafers or pellets bonded to a recess in brass or stainless steel. These cells can be made to react to tension, strain, displacement, velocity, acceleration, vibration, or rotation. Their sensitivity range is stated to extend from 250,000 psi, as used for the testing of explosives, to 1 milligram, as required in biological research. In addition to high sensitivity, the cells have a high output, thus eliminating the need for amplifiers when used for the operation of relays, recording instruments, and other controls. Their simple construction, which consists of two electrical contact surfaces with the sensitive material between them, gives them an unusually wide range of application. The resin is also available as a pressure-sensitive paint, into which metals can be dipped; alternatively, it can be sprayed onto the metal surface. The high sensitivity of these cells is the result of an exceptional increase in relative electrical resistance as no-load pressure is approached, ranging from about 15:1 for cells with a no-load resistance in terms of ohms, and over 3,000,000:1 for cells with a maximum resistance of 100 megohms or more. Maximum resistance and change in resistance with load are regulated during manufacture by a heat-treatment process. Dynamic response usually is about 60 cps, but can be increased to as much as 3000 cps.

• *SPRAYED-ALUMINIUM GASKETS*

Conventional gaskets for large-diameter openings often require splicing because of size limitations. When sealing fluids at low temperature, ductile gasket materials are limited to the fluorinated hydrocarbons, or combinations of these with asbestos fibre. With soft metals such as copper, sealing pressures are excessive for large diameters, even with tongue-and-groove construction. According to a recent report, a new technique for sealing large flanged openings in tanks, bulkheads, and piping uses a coating of aluminium sprayed onto the coverplate, without the need for an inserted gasket. It is claimed that this sprayed-aluminium gasket has the advantage of an unspliced seal and the ductility required for low-temperature applications. This method is said to be useful in any equipment handling low-temperature fluids, such as pumps, automatic valves, reservoirs, surge cylinders, and couplings. The components of the closure are two flat, mating surfaces, one of which has two parallel rectangular tongues or beads, about 0·04 in. wide by 0·032 in. high, these being machined into the flange, one inside the bolt circle and the other outside. The spray is applied

"I WAS A WASTER!"

—*STEAM PIPE CONFESSES*



"I am a four-inch bore pipe. I work in a factory. It is my job to carry steam at 450°F. from generator to the plant. But I was a waster, a fuel waster, a *very* fuellish waster indeed!

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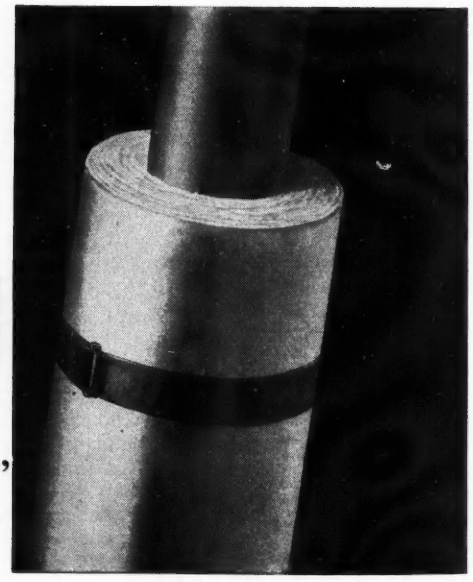

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to the flat mating coverplate, using standard metallizing techniques for aluminium alloys, the coating being built up to 0·032 in. thickness. To prevent oxidation, inert gas is used to carry the molten aluminium spray. It is claimed that metallized aluminium gaskets can be applied to many structural-metal bases, but mating flanges should be made of material with similar expansion coefficients. The re-use of a joint is limited, because the sprayed coating deforms permanently each time the seal is made. It is stated that with care, however, a joint may be coupled and uncoupled three or four times.

● *HIGH-TEMPERATURE CERAMIC SEALS*

The constant search for ceramic seals which will not crack when subjected to thermal shock has produced a new material which is claimed to be especially suitable for high-temperature applications. An outstanding characteristic of the material is said to be the fact that its electrical properties are several thousand times better than those of glass seals, while at the same time it can be bonded physically to most stainless steels. It has exceptional ability to withstand severe physical and thermal shocks, even those occasioned by heating to 800°F and then quenching in ice-water. The heating required by the sealing process causes unique changes in the linear expansion properties of the material itself and also of the stainless steel, the result being a common coefficient of thermal expansion, permitting crystalline migration between the interfaces of the materials during the cooling cycle. Thus, an actual molecular bond exists between the metal and the ceramic, ensuring a highly reliable, leak-tight seal. The electrical breakdown voltage of the ceramic is claimed to be extremely high, making it specially suitable for high-voltage feed-through applications at high temperatures. No actual figures of breakdown strength are given in the original report, which also lacks any data on the composition of the material. The material is available in two forms, i.e., preformed beads and complete seals. The preformed beads are primarily intended for use in the manufacture of transistors, diodes, and similar products, and are produced to exact dimensions by compressing the material in precision dies and then sintering it. The actual firing is then carried out by the user.

● *CONTAINERS FOR MOLTEN METAL*

A recent invention relates to containers for molten metal, including crucibles and furnaces for use in melting metals of high melting point, such as titanium and its alloys. It is known that ordinary refractories or ceramics will not stand up to the attack of molten titanium and titanium alloys. The melting point of titanium is in the region of 1700 to 1800°C and, as the metal has a high affinity for oxygen, nitrogen, and carbon, the ordinary refractories are subject to chemical attack, even when melting is carried out in a vacuum or in an inert gas such as argon or helium. The use of graphite-lined crucibles for melting titanium is open to the objection that the metal tends to pick up a higher proportion of carbon than is generally acceptable. The new proposal envisages the use of a graphite container which has a refractory lining composed of the carbide or carbides of niobium and/or hafnium, which have a binding energy so high that the lining material is not appreciably dissociated by the action of the molten titanium. One method of producing such a lining is to use a metal foil of niobium which may have hafnium carbide sintered to one of its faces. This foil is inserted as a lining into a graphite crucible, the niobium foil being next to the graphite. When the metal is heated in contact with the graphite to a high temperature, e.g., 1750°C, the niobium metal will sinter to the graphite, forming an interface binding of niobium carbide. Another method would be to take the metal compound in powder form, and then to compress and sinter it by the usual powder-metallurgy technique.

● *AUTOMATIC ZONE REFINING*

Utilizing the zone-refining technique in which a molten zone is swept through a material, carrying impurities with it, a new automatic refining device for silicon, germanium, molybdenum, tungsten, and many other materials is stated to achieve such a high level of purity that it may lead to the manufacture of improved transistors, diodes, and other semiconductor devices. The new apparatus comprises a 10-kW, 4-Mcs generator, a mechanism for moving the rod to be purified up and down whilst rotating inside a gas-tight silica enclosure, and switching devices for automatically recycling the mechanism. In the case of silicon, owing to its high resistivity, the rod must be heated to about 800°C by conduction from a molybdenum chuck heated by a radio-frequency generator. Power is then absorbed by the rod itself, all subsequent operations being automatic. The power is increased to a preset value, sufficient to produce the desired molten zone at a preset location, and the motor drives for the mechanism are then started, rotating the rod and moving it downwards, so that the molten zone traverses the rod from bottom to top. A limit-switch stops rotation when the zone reaches the top of the rod and decreases the power to a preset value, sufficient to keep the now solidified zone at 120°C. The heated zone is then returned to its previous position near the bottom of the rod, and automatic recycling continues as long as desired. Constant length and freedom from mechanical oscillations of the

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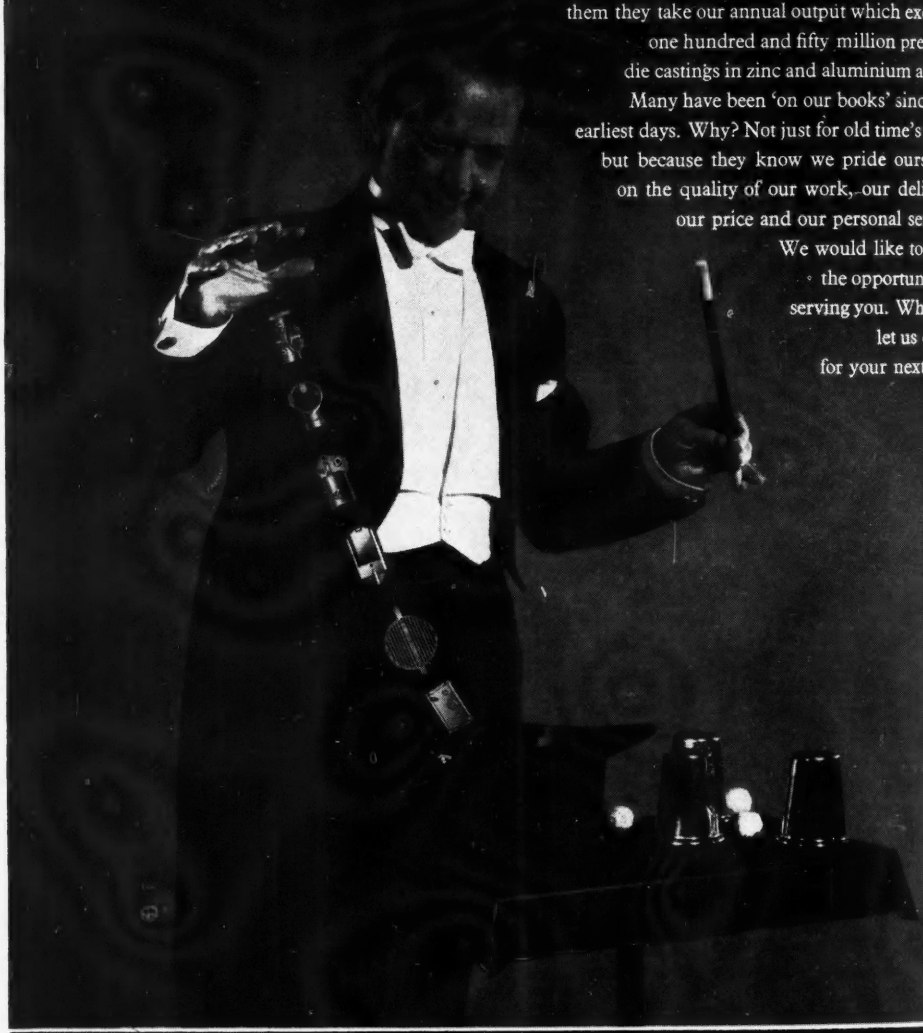

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molten zone are ensured by the use of low heating currents at relatively high frequency and by correctly proportioned load and generator impedances. Crystals of uniform length are obtained by controlling the ratio of zone length to rod diameter. It is stated that, by means of this equipment, it has been found possible to reduce the chemically active impurities in silicon after 67 passes to less than one part in 10^9, producing what is believed to be the purest silicon ever made in quantity.

● *DOUBLE-ORIENTED MAGNETIC SHEET*

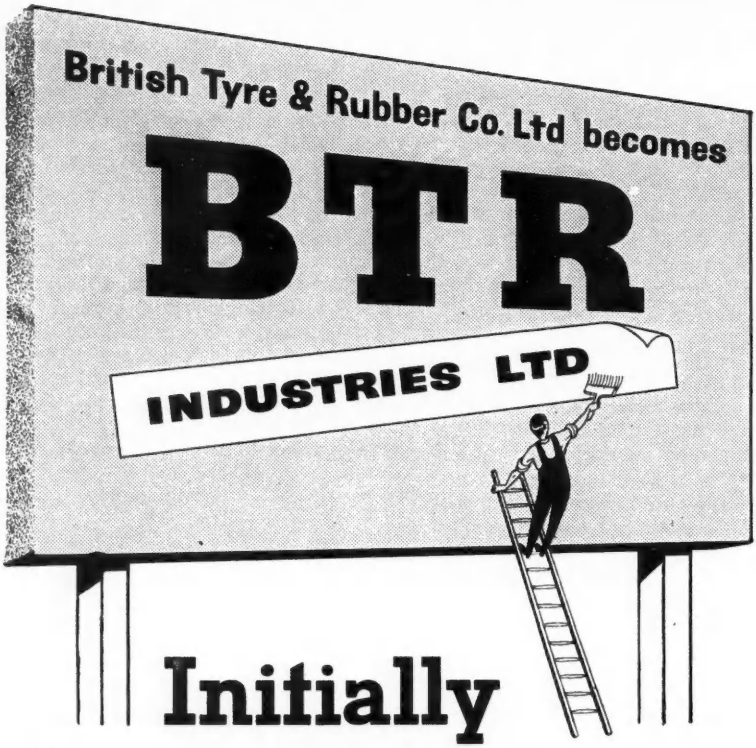
Designed to increase the efficiency of transformers, motors, and generators, a new type of silicon-iron magnetic sheet has a double-oriented four-square effect, giving excellent magnetic properties not only backwards and forwards along the sheet but also across it. This effect is produced by a different type of alignment, known as " cube texture ", to that used in the production of single-oriented sheet, and, although the basic raw material is a form of silicon iron similar to that of the " soft " magnetic sheet used in transformers and motors, rigid control of the internal structure of the metal during all processing steps is essential for the production of double orientation. By suitable lining up of oriented sheet in transformers, etc., it has been found possible to carry most of the magnetic flux in the resulting " easy " directions. Thus, currently used sheet has reduced transformer-core losses to about 10% of those of the original unalloyed iron and to about 20% of those of the original silicon-iron alloy. The new double-oriented sheet promises even further improvements in efficiency.

● *INERTIA COMPENSATION FOR CYLINDER PRINTING-PRESSES*

During the reciprocating movement of the type-bed of a cylinder printing-press considerable inertia forces arise and these increase with the operating speed. For compensating these forces, air buffers are commonly used to absorb the movements of the type-bed at the reversing points, and the energy stored is used for assisting the reversing movement. The length of the buffer cylinders has permitted their use only with those types of mechanical press in which the type-bed, after covering a certain distance at constant speed, is slowed down to a standstill and is subsequently accelerated. With non-uniform type-bed movements, such as sinusoidal movements, e.g., in stop-cylinder presses, it is not possible to use air buffers, although considerable inertia forces arise with such movements. A design has now been proposed in which the inertia force of the reciprocating bed of a cylinder printing-press is compensated by means of an air compressor. This air compressor has a piston which oscillates in a closed housing, the piston being driven in alternate directions by a shaft of the type-bed drive. The oscillating piston swings in a closed housing, in which a partition wall is provided, so that the air enclosed between the piston and the partition wall is alternately compressed and expanded. In this way a simple and uninterrupted compensation of the inertia forces occurring during slowing down and acceleration of the type-bed is achieved. The compressor casing can be provided with holes or slots which divide the piston stroke into compression sections and into sections where no compression takes place. It is claimed that this type of compensation is suitable for stop- and swinging-cylinder machines and also for single- and two-revolution machines. By suitable arrangement of the slots in the casing it is possible to adapt the compression curve to all types of movement employed. It would appear that this type of compensation may be found useful for other types of reciprocating mechanisms requiring inertia compensation.

● *IMPROVEMENTS IN TITANIUM ALLOYS*

A recent publication points out the intense efforts which are being made to improve existing titanium alloys. These efforts meet with considerable difficulties, because any new alloy must not only be made consistently in commercial quantities and sizes, but must also possess diverse fabrication characteristics and mechanical properties. Formability, weldability, high strength, and creep resistance at elevated temperatures are outstanding requirements to be met. Creep resistance can be improved by alloying elements which stabilize the alpha phase. For this purpose, aluminium is most frequently used, since it increases creep resistance and does not impair weldability. While such alloys are more difficult to form, and the strength and formability of single-phase alloys cannot be improved by heat treatment, they are said to be well worth considering where welded component parts which must possess resistance to stress at elevated temperatures are involved. Much better formability can be obtained in alloys which can be solution-treated to retain the beta phase. Among the beta stabilizers in use are vanadium, molybdenum, chromium, iron, and manganese. A major difficulty with many present alloys of this kind is their loss in strength and creep resistance with increasing temperature, and the fact that they suffer from embrittlement. A recently developed alloy contains both an alpha and a beta stabilizer and is believed to have some of the best characteristics of the two main types. This titanium alloy, which contains 2·5% aluminium and 16% vanadium, can be formed in the solution-treated



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condition and is to be used in the age-hardened state. A second titanium alloy which is of the all-alpha type has been developed as a weldable sheet and bar alloy for use at high temperature, and contains 8% aluminium, 2% niobium, and 1% tantalum.

● *BATTERIES WITH SOLID-WAX ELECTROLYTES*

It is reported that a fundamental investigation of the chemical and electrical properties of batteries made with solid-wax electrolytes is now in course of progress. This new field of battery research is expected to provide information of value not only in fabricating batteries but in understanding the phenomena taking place in wax electrolytes subjected to electric fields. In the course of this investigation, a low-current punched-cell battery has been developed which has a waxy electrolyte consisting mainly of solid polyethylene glycol. This battery is not only compact and easily constructed, but produces a high voltage, even after long-term storage. It is stamped from a three-layer sandwich consisting of a zinc sheet and a conductive vinyl film, between which is a separator impregnated with a zinc chloride/polyethylene glycol mixture and coated on one side with manganese dioxide. Among other applications, the battery is expected to prove useful in maintaining a charge on a capacitor and in producing a grid-bias voltage for radio valves. Several 25-cell wax-electrolyte batteries have been constructed, these being 0·3 in. in length and having an e.m.f. of 37·5 V. Two different sizes of these batteries have been produced, i.e., one of 0·25 in. diameter, weighing 0·05 oz, and with a short-circuit current of 3×10^{-8} A, and the other 0·5 in. in diameter, weighing 0·2 oz, and with a short-circuit current of 3×10^{-7} A at ordinary temperatures. Although different weights of polyethylene glycol were initially used, there are hardly enough data on glycol electrolytes to permit well-founded generalizations regarding the effect of molecular size on short-circuit current.

● *SUPERSONIC WAVE-IMPULSE CARDIOGRAPH*

A recent patent specification describes a supersonic wave-impulse cardiograph which has interesting electronic features. The apparatus employs the echo impulses formed by the muscles of the heart or the wall of the heart when subjected to supersonic impulses. When using such an apparatus the observer is frequently interested in obtaining on the viewing screen only those pictures of the echo impulses of the supersonic-impulse cardiogram which exceed a predetermined magnitude. Thus, for example, the observer may wish to suppress small echo impulses coming from unimportant areas of the body being investigated and having nothing to do with the larger echo impulses. For this purpose, the supersonic wave-impulse cardiograph includes a discriminator with an adjustable pass range, to the input of which are conducted the echo impulses transmitted by the receiver part of the cardiograph. The output of the discriminator is connected to a device for brightening the cathode-ray beam of the oscillograph tube. The observer then adjusts the discriminator to a suitable pass range, so as to see on the screen the smallest echo impulses of interest, but no others. The device for brightening the cathode-ray beam is controllable, so as to permit variations of the intensity of the cardiogram. As the movements of the heart are as a rule strictly periodic, it is desirable to show the periodic heart-beats synchronously superimposed on the viewing screen. This will then enable the observer to recognize directly alterations occurring within the corresponding periodic sections of the cardiogram. For this purpose, a special synchronizing device is incorporated in the apparatus.

● *STRESS-FREE NICKEL PLATING*

Most nickel deposits are characterized by high values of internal tensile stress, stress values as high as 60,000 psi having been recorded. Such stresses cause peeling, cracking, crazing, warping, blistering, distortion, shrinkage, and failure of the plated metal. A sulphamate bath has now been developed which is claimed to give nickel deposits which are stress-free and have high tensile strength. In addition, the deposits are smooth and ductile, and have a slight sheen and a fine-grain structure. Chloride inclusions are held to a minimum. Hardness of the deposits can be controlled within the range of 200 to 550 VHN, and ductility ranges from 30% elongation in 2 in. to as low as 6%, while tensile strength can be varied from 60,000 to 130,000 psi. It is claimed that stress corrosion is eliminated, since the deposits do not have any appreciable stress. Sulphamic acid, which is similar to sulphuric acid, is a white, crystalline, inorganic solid which is non-hygroscopic and non-volatile. The acid is moderately soluble in water and produces solutions which are highly acid and compare in pH value with those of nitric, sulphuric, and hydrochloric acid. Metal sulphamates are obtained from the reaction of an oxide or carbonate of the metal. It is emphasized that the pH-value of the bath must be carefully controlled within the limits of 3·0 to 4·5. As the pH-value increases, the compressive stress and the hardness of the deposit also increase, with consequent detriment to the coating. The bath temperature is closely controlled between 100 and 140°F, as the hardness of the deposit decreases with an increase in temperature.

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VOL. XVIII No. 11 NOVEMBER, 1957

Surface Preparation for Protective Linings and Coatings used in Critical Service

By S. J. OECHSLE, JR. and K. G. LEFEVRE*

ALTHOUGH it is known that a coating compounded and manufactured to adhere to a metallic surface will be satisfactory only when the molecules of the coating are permitted to come into intimate contact with the molecules of the metallic surface, improper surface preparation continues to be a primary cause of lining failure.

There are three primary causes of coating failure, all of which are the evident results of improper surface preparation. These causes are loss of adhesion, osmotic blistering, and under-film corrosion.

Loss of adhesion results from the presence of foreign matter, which prevents a lining from making direct contact with the base metal. Any foreign material may be at fault, e.g., mill scale, rust, paint, dirt, grease, oil, and chemical deposits.

Osmotic blistering occurs when soluble salts or other chemicals which are soluble in water remain on a surface during application of the coating. The fluids cause blistering by passing from a dilute solution to the more concentrated solution behind the coating. The more these chemicals are trapped by the lining, the more aggravated will be the blistering condition and the more rapid will be the total failure of the system.

Under-film corrosion is usually due to eating away of the base metal by chemicals covered by the lining at the time of installation.

When considering techniques for proper surface preparation, it should be understood that, quite apart from such accepted procedures as sand-blasting, etching, and cleaning, design considerations are also of importance and, in fact, proper surface preparation often commences with the original design of a vessel.

DESIGN CONSIDERATIONS

From the point of view of linings, the fundamental principle in designing process equipment is that all areas to be lined should be as smooth as possible, and that all sharp edges and discontinuities should be eliminated. In this connection, it will be appreciated that any lining applied in liquid form tends to flow out or away from sharp discontinuities such as weld spatter, weld undercuttings, or sharp edges, and the thickness of the lining is always less at these points. Thus, on an 8-mil lining over the entire surface, it is reasonable to expect not more than 1 mil over any unground edges.

Changes in direction of the base material should be as gradual as possible. Also, cracks, pinholes, sharp corners, and even the line of contact between two pieces of metal can form areas over which coatings can bridge, allowing air, moisture, and other elements to be trapped behind the lining. Naturally, it is unreasonable to expect proper lining of an area which cannot be reached, such as angles which are placed back to back or which are skip-welded over a plate.

Sheet lining is subject to the above considerations, particularly with regard to trapped air, which can cause major difficulties. The inorganic salts of the weld flux can react with either the paint or moisture to form undesirable products.

New Installations:—

The above principles are relatively easy to apply in the case of the design of new installations, provided that a lining has been anticipated. The following simple recommendations are, however, desirable:—

(1) Butt-welded vessels should be specified in preference to lap-welded or riveted vessels.
(2) Flanged and dished heads should be specified in preference to flat heads.
(3) Oversize and flanged outlets should be used.
(4) The storage vessel should have a self-supporting umbrella or elliptical roof.
(5) Where internal columns must be used, their number should be reduced to a minimum and they should be tubular.
(6) Any type of construction involving pockets or crevices should be avoided.
(7) Stiffener members should be external to the vessel.
(8) Any weld spatter and weld flux must be removed.
(9) All welds must be free from under-cutting, cracking, and pinholing.
(10) All welds must be suitably ground for the anticipated lining.
(11) The interior use of rolled structural members such as angles and channels in a back-to-back position or lying flat against the vessel should be avoided.
(12) The use of any arrangement in which the chemical is pocketed and cannot drain must be avoided.

Existing Installations:—

Admittedly, even in new vessels, all the above recommendations may not be entirely practical. In the case of existing installations, conformity may be virtually impossible, and the problems encountered in making all surfaces smooth and satisfactory become quite complex. However, even here, a number of recommendations can be given, as follows:—

(1) When structural members, e.g., channels or angles, are used back to back or as internal stiffeners, they should be seal-welded on all sides where they touch other metal.
(2) All lap-welds should be seal-welded inside and outside.
(3) Seal-welding on existing tanks should be carried out at as low a temperature and as rapidly as possible,

*Protective Coatings Division, Metalweld Inc., Philadelphia, Pa.

to avoid crystallization effects and consequent magnification of stress-corrosion problems.

(4) All weld spatter and flux should be removed, and all welds should be suitably ground for the anticipated lining.

(5) All sharp edges should be ground to at least $\frac{1}{32}$ in. radius.

(6) All pockets, sections, and crevices must be self-draining.

(7) Mastics, as fillers of cracks and fillets, should be used with great care and only in accordance with the manufacturer's specifications.

In addition, in the case of riveted tanks, special care must be exercised. All rivets and overlapping plates should be caulked tight, and this may prove to be a satisfactory preparation. Often, however, the " hats " on rivets and the discontinuity on laps, particularly when three plates come together, present a crevice condition which is unacceptable to the lining. Furthermore, if it is considered desirable to ring the rivets with weld metal and to seal-weld the laps, this treatment must be extended throughout the whole tank, usually giving rise to other problems. The appropriate use of a mastic or sprayed metal can, however, sometimes be used to make the entire problem less severe.

Sand-Blasting, Etching, and Cleaning

There are three accepted specifications for sand-blasted steel, i.e., white metal, commercial, and brush-off. White metal implies complete removal of all mill scale, rust, rust scale, paint, or other foreign matter, leaving the surface a uniform grey-white metallic colour. The commercial specification includes the removal from steel of all corrosion products, as well as mill scale, but does not include removal of the grey oxide binder between the scale and the steel. The finished surface has a grey colour and appears rather streaky. Brush-off includes only the removal of loose mill scale, loose rust, and loose paint. The remaining foreign matter should be tight and the surface sufficiently abraded to provide an anchor pattern.

Insofar as the actual mechanics of surface preparation are concerned, a thoroughly cleaned surface, i.e., one completely free from rust, scale, grease, etc., obviously furnishes the best possible base on which to apply a protective lining. In actual practice, however, this ideal condition cannot always be obtained, so that the practical problem regarding normal maintenance painting usually becomes one of finding a suitable compromise. Nevertheless, it should be mentioned that no compromise is possible in the case of immersion, and only in extenuating circumstances should a compromise be made in areas exposed to concentrated vapour or spillage.

In any surface preparation, the desirable goal is a white metal surface. The basic premise is that a product tends to be insulated when a paint or coating system is applied. This insulation is intended to exclude detrimental products from the surface of the base material, but at the same time will retain under the paint film any detrimental products which have not been removed before application of the new coating. Common failures caused by adhesion loss, osmotic blistering, and under-film corrosion result rather quickly when a coating is immersed.

Even when the surface is brought down to a grey metal, it is possible for sulphides and even sometimes for paraffin to be left on the surface after sand-blasting. Washing with water and time to oxidize (in the case of sulphides), solvent cleaning, and reblasting (in the case of paraffin) may be in order. There are cases where stronger reagents, such as acids, must be completely neutralized after initial sand-blasting before the coating or lining can proceed.

Types of Surface and Cleaning Rate:—

In any sand-blasting operations, appropriate equipment must be used, and requisites include the use of an adequate air supply, a pressure-type sand-blast pot, air and blast hose of the correct size, and adequate ventilation and lighting. In addition, a classification of the surface involved must be made, this classification being divided into various types, as follows:—

(I) Steel, tight mill scale, no rust.
(II) Weathered steel, loose mill scale, fine rust, no pits.
(III) Weathered steel, no mill scale, rust, some pits.
(IV) Old steel, severe pitting.
(V) Steel, thin lining, small percentage breakdown.
(VI) Steel, thin lining, overall breakdown.
(VII) Steel, sheet lining removed, some adhesive remaining.

In Table I the approximate cleaning rate and quantity of abrasive required for the above classified types of surfaces are given for a white metal specification, using an air pressure of 90 psig and a $\frac{5}{16}$-in. nozzle.

As mentioned, the above table gives indications of the cleaning rates for a white metal surface, as recommended for critical service. However, for purposes of comparison, it may be mentioned that, if the rate for white metal is 100 sq ft/hr, the corresponding rate for a commercial blast would be 370 sq ft/hr, and for a brush-off blast 870 sq ft/hr.

Table I: Cleaning Rate for a White Metal Specification with Various Types of Surface, using a $\frac{5}{16}$-in. Nozzle and 90-psig Air Pressure.

Type of Surface	Cleaning Rate (sq ft/hr)	Quantity of Abrasive (lb/sq ft)
I	100	12
II	120	10
III	110	11
IV	60	20
V	70	17
VI	80	15
VII	50	24

The above data should be considered as average figures, because of the many variables involved, including scaffolding and hose-friction loss. In some cases, the previous service of a vessel has an effect on the type of rust or scale. It is also important to bear in mind that any change in air capacity, air pressure, and nozzle size influences the production rate and the amount of abrasive consumed. Thus, for example, with a $\frac{3}{16}$-in. sand-blast nozzle, the volume of air required at 90 psig is about 52 cfm and the rate of sand flow about 500 lb/hr, whereas, with a $\frac{1}{4}$-in. nozzle these amounts would be 94 cfm and 900 lb/hr, rising to 210 cfm and 1700 lb/hr for a $\frac{3}{8}$-in. nozzle, and 375 cfm and 3000 lb/hr for a $\frac{1}{2}$-in. nozzle.

Depth of Etch Required:—

Considerable thought has been given to the proper selection of blast abrasive. As a rule of thumb, the etch should not exceed one-third of the final thickness of the coating or lining from the highest peak to the lowest valley. As examples of the etches given by various abrasives (assuming an air pressure of 90 psig and the use of a $\frac{3}{8}$-in. nozzle), it may be mentioned that fine sand (passing through a 40-mesh screen) gives a 1·9 mil etch, medium sand (18 mesh) a 2·5 mil etch, and coarse sand (12 mesh) a 2·8 mil etch. G-50 grit (25 mesh) gives a 3·3 mil

(*Concluded on page 514*)

An Analysis of the Probability Theory of Fatigue

By A. Ferro and R. Colombo. (From *La Metallurgia Italiana*, No. 7, 1957, pp. 518–522, 3 illustrations.)

The probability theory of fatigue of materials was initially proposed by Freudenthal[1] in 1946 and extended in subsequent publications.[2,9] The theory assumes, in substance, that, if P is the probability (a very small value with an approximately normal distribution) of rupturing a local bond in a loading cycle, the probability of rupture of other bonds in subsequent cycles is equal in each of these cycles, and therefore the failure of the testpiece, regarded as a rupture of a fairly large number m of bonds in N cycles, is given simply by the law of independent probabilities, i.e.,

$$F = 1 - (1-P)^{mN} \quad .. \quad .. \quad (1)$$

where F is the cumulative probability of rupture of all m bonds and $(1-P)$ is the probability of survival of one bond for one cycle.

By transforming eq. (1) and tabulating for various values of mN and P, it is possible to show that the shape of an S-N curve is approximately represented by

$$S_1 - S_2 = K(\log mN_1 - \log mN_2) \quad .. \quad (2)$$

where S_1 and S_2 are two stress levels and K is a constant. The theoretical curve plotted on a logarithmic scale for N is thus very nearly a straight line, and this agrees with the shape of experimental fatigue curves for a considerable portion of their length.

In a further analysis, based on the theory of extreme values relating to the effects of volume, Freudenthal[2] showed that, by assuming a Laplace exponential distribution for the probability of rupture in one cycle, the S-N curve obtained is rigorously a straight line in a one-way logarithmic diagram.

It should be noted that, with Freudenthal's hypothesis, the problem of determining the shape of a fatigue curve $S = f(N)$ is reduced to that of finding the position of the central value of the distribution of extreme values of a variable when the magnitude of the sample increases.

This type of calculation was developed by various mathematicians, particularly by Gumbel[3] and by Fisher and Tippett.[4] For initial distributions of the exponential type, Gumbel has shown that the final distribution for large N values is always of the type

$$P = e^{-e^{-x}}$$

Epstein[5] has extended the theory by employing it to assess the relative importance of the size effect on the rupture of materials. The volume of a test specimen is in this respect analogous with the number of stress cycles.

Although Freudenthal's work emphasizes the point that, with a suitable value of K in the hypothesis of independent probability, the correct shape of the fatigue curve is obtained, it does not apparently take into consideration the fact that the hypothesis also necessarily includes a relation between the shape of the curve and the scatter.

Now, the shape of the curve, with K taken as an arbitrary constant, does not seem in itself sufficient to establish that the probability hypothesis is valid, whereas the determination of a possible correlation of variance with the parameters of the S-N curve may perhaps provide a more reliable test of the theory. It was therefore decided to re-examine the problem from this point of view.

Freudenthal's schematic representation of the fatigue process presupposes that the linear, or nearly linear, relation between stress and the logarithm of the number of cycles is due to a purely fortuitous occurrence of rupture. Physically, this is equivalent to assuming that the individual stages of rupture are initiated by or involve factors which are variable from one cycle to the next. Freudenthal first suggested that the accidental factors in the fatigue process are fluctuations of thermal oscillations in the lattice, with sufficient amplitude to cause rupture of a bond ; it may be noted, however, that, with this hypothesis, the fatigue of metals should depend on the frequency of application of the loading cycles.

Having mentioned these concepts and the question of the suitability of the model, it seems appropriate to determine more precisely whether or not the experimental material available agrees with the probability hypothesis. This assessment may also be of some use in understanding the mechanism of fatigue itself.

The experimental information contained in an S-N curve is basically the shape of the curve and the variance, and hence the standard deviation of S and $\log N$ for various values of N.

In the normal S-N curve, the first-order coefficient, i.e., the slope of the curve, can usually be determined fairly accurately, but the second-order coefficient is only approximately known[6]. Furthermore, as regards the scatter of the results, the only values known with some degree of accuracy are the variances of stress and of $\log N$. Both distributions are generally regarded as normal but, since they are known only for the central region, many other types of function giving a linear variation of cumulative probability in the vicinity of the modal value are equally possible, and have, in fact, been proposed by various authors, e.g., by Weibull[8].

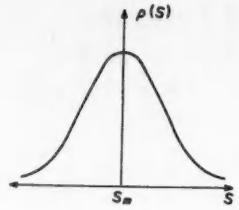
However, the theory of extreme values used by Freudenthal requires an exact knowledge of the type of probability distribution function, because it is necessary to be able to extrapolate the cumulative probability up to values very close to unity. If the distribution function is chosen in some arbitrary manner, there can be no certainty as to the validity of the probability hypothesis, since obviously any type of fatigue curve can be obtained with an appropriate function. Analogous considerations apply with regard to the problem of the size effect[5].

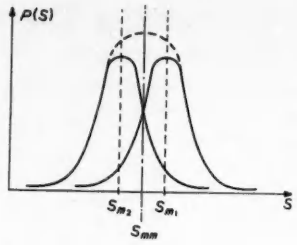
Moreover, it is worth noting at this stage that the scatter to be regarded as significant for the statistical theory of fatigue is the purely " casual " dispersion due to the fact that each cycle represents an independent attempt to produce an event, which ultimately leads to the rupture of the specimen ; in other words, if it were possible to perform an experiment in which the same specimen could be loaded to rupture several times in succession, or, alternatively, if it were feasible to produce a number of ideally identical specimens in an identical manner, there should still be differences in endurance (i.e., in the number of cycles to failure), to correspond to Freudenthal's purely statistical concept of fatigue.

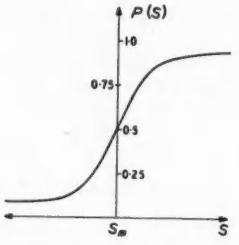
The scatter resulting, for instance, from minor variations in strength from one specimen to the next, from small defects in the material, from intrinsic differences in specimens, etc., should not be regarded as a " casual probability " dispersion.

Relation between Shape of S-N Curve and Statistical Distribution

Let $P(S)$ be the cumulative probability of rupture







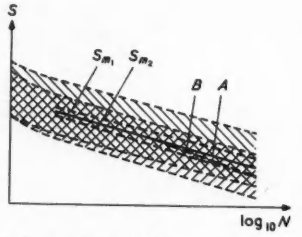


Fig. 1 (left). Relative probability density $p(S)$ and cumulative probability $P(S)$ as functions of stress, at a constant number of load cycles N.

Fig. 2 (right). Widening of the curve of probability density as a result of the presence of two groups of specimens.

after N cycles, so that the relative probability density $p(S)$ is

$$p(S) = \mathrm{d}P/\mathrm{d}S \quad .. \quad .. \quad (3)$$

To simplify matters, let it be assumed for the time being that the scatter of the pure probability theory and the experimental scatter coincide. Then, passing from a number N of loading cycles to another number $N + \Delta N$ only slightly different, it can be seen that the relation (1), obtained through the assumption of equal and independent probabilities in the various groups of cycles, can be rewritten in the form :

$$[1 - P(S-\Delta S)]^{(N+\Delta N)/N} = \text{constant} \quad .. \quad (4)$$

For sufficiently large values of N it is possible to use infinitesimals, and for the neighbourhood of the corresponding modal value (of the mean fatigue curve), where $S = S_m$ and $P(S_m) = 0{\cdot}5$, as in Fig. 1, eq. (4) can be written

$$[1+(\mathrm{d}N/N)] \log [1 - P(S - \mathrm{d}S)] = \log 0{\cdot}5 = -0{\cdot}69 \quad (5)$$

Then, using a series expansion for the logarithm and noting that

$$P(S_m - \mathrm{d}S_m) = P(S_m) - p_m \mathrm{d}S_m = 0{\cdot}5 - p_m \mathrm{d}S_m \quad (6)$$

the result obtained is

$$(\mathrm{d}\ \log N)/\mathrm{d}S = 2p_m(S_m)/0{\cdot}69 \quad .. \quad (7)$$

This result is fully analogous with the more general expression obtained by Gumbel[3] with a slightly different derivation for very large values of N, starting from the initial distribution for $N = 1$.

For dispersions of fatigue results which can be regarded as being represented by curves not very different from the Gaussian curve, it may be considered that $P(S)$ can be approximated by a straight line in the interval $0{\cdot}5 \pm 0{\cdot}34$ (over a range equal to twice the standard deviation μ_s), so that, for convenience, using logarithms to base 10,

$$P_m(S_m) \cong 0{\cdot}68/(2\mu_s) \quad .. \quad .. \quad .. \quad (8)$$

and $$\mathrm{d}S/\mathrm{d}\log_{10}N \cong \mu_s/0{\cdot}42 \quad .. \quad (9)$$

The slope of the S-N curve at every point is, therefore, simply proportional to the deviation of stresses. Moreover, it may also be assumed that the endurance N has an approximately normal distribution in the region in which the curvature of the S-N curve (plotted on a logarithmic scale for N) is small, so that

$$\mu_{\log_{10}N} \cong \mu_s \mathrm{d}(\log_{10}N)/\mathrm{d}S \quad .. \quad (10)$$

From this it evidently follows that

$$\mu_{\log_{10}N} \cong 0{\cdot}42 \quad .. \quad .. \quad (11)$$

Therefore, in the " probability " hypothesis and within the limits of the approximations made, the deviation of $\log_{10}N$ is a pure number, which is independent of the nature of the material.

This result follows from the fact that the distribution function $[1-P(S)]^N$, which is not very different from an exponential function, is shifted parallel to itself when $P(S)$ is varied as a function of $\log N$. If, in addition, the variation of μ_s is known as a function of $\log N$, eq. (9) can be integrated. For μ_s = constant, the curve of $S = f(\log N)$ is a straight line, so that the same result is found as that provided by the theory of extreme values for an exponential distribution (see eq. (2)).

To sum up, a " pure probability " theory of fatigue involves two consequences, i.e., (1) the standard deviation of $\log N$ is a constant, independent of the material (at least in a first approximation), and (2) the slope of the S-N curve is proportional to μ_s (the deviation of S) at every point. If, as is generally the case, μ_s does not vary appreciably as a function of $\log N$, the S-N curve deviates little from a straight line. If μ_s decreases for increasing numbers of cycles, the curve is concave upwards.

It may further be noted that the probability hypothesis also involves for large N-values some consequences[3] regarding the shape of the statistical distributions in S and in N. However, these are not directly applicable because, as previously stated, the shape itself depends to too great an extent on other causes of scatter of the non-probability type.

The scatter considered in the above formulae is solely that obtained from probability considerations. Experimentally, however, only overall values of scatter can be determined, corresponding to all the factors (material, etc.) which give rise to variations in the fatigue limit. Now, if in trying to allow for this fact, it is assumed possible to subdivide the complete set of ruptured specimens into two groups of equal individuals with only a slight difference in strength, each group having its S-N curve, S_m-value, and distribution function, it can be seen immediately that, with the alternative assumption that there is only a single set of specimens to be considered, a distribution function can be calculated which is broader than the two partial functions, as illustrated in Fig. 2, which shows the widening of the curve of probability density, owing to the presence of two groups of specimens, and the effect on calculation of the slope of the fatigue curve, B being assumed, instead of A, to be the corresponding fatigue curve.

As a rule, the dispersion of S due to the non-probability factors (variations in strength, small defects, etc.) can be regarded[7] as being independent of N. If the prob-

ability hypothesis is exact, the scatter band of the specimens should then be obtainable as the sum of the two portions, of which the first is the constant deviation of $\log N$, independent of the material and approximately equal to 0·42, while the other is the deviation in S, also constant and equal to some percentage of the stress level, but depending on the material and the characteristics of the specimens (Fig. 3).

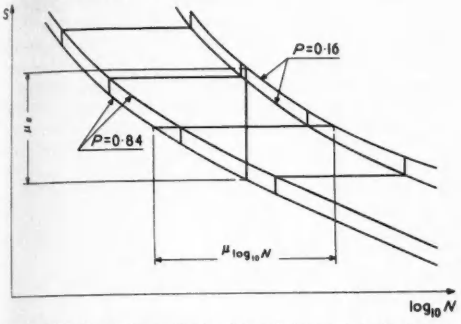


Fig. 3. **Widening of the scatter band in a fatigue test, owing to non-probability factors.**

The scatter of $\log N$ according to the probability hypothesis should then always be greater than the theoretical value of 0·42, and, if the material has a fatigue limit (i.e., if the slope of the curve becomes zero at a certain point), it should tend towards infinity. However, if the fatigue limit exists, i.e., if the mean S-N curve ($P=0·5$) becomes horizontal at some point, the μ_s-value of the stress level at this limit will certainly be due only to the non-probability factors. Thus, for materials which have a fatigue limit or for which the S-N curves are concave upwards to a notable extent, a criterion may be formulated which, even if it is somewhat rough, should make it possible to distinguish between the portion to be regarded as a "probability component" and the other causes of scatter. This criterion is that the deviation of S should be larger in the region of the curve where the slope is greater. On the other hand, if no account is taken of the scatter due to non-probability factors in calculating the slope of the S-N curve by means of eq. (9), the value which can be expected will evidently be greater than that resulting from the correct application of the theory (Fig. 2).

Analysis of Experimental Results and Conclusions

Before reviewing the results of this analysis, it is necessary to add that the "probability theory", if it is valid, will apply only for large numbers of cycles and should therefore be verified solely in this region.

The physical facts of the process indicate, in any case, that neither the initial period of fatigue is in accordance with the probability hypothesis, since the material strain-hardens during this period, nor is the final period, in which an initially microscopic crack spreads until rupture occurs. Both are cases in which the mechanism of fatigue progresses in a well-determined manner.

The probability hypothesis, therefore, can be applied only to the intermediate period, in which the nuclei are formed for submicroscopic cracks, of which one subsequently becomes capable of developing. Considering, then, the entire duration of the fatigue process, it can be stated that the hypothesis will be applicable only if this intermediate period is long enough relative to the other two.

Recent investigations[8–11] have shown that, at large numbers of cycles, this period can be of considerable duration and (a point in support of the hypothesis) it contributes in a preponderant manner, at least for light alloys, to the scatter of the results.

Analysis of the experimental results was therefore carried out only for large numbers of cycles within the limits of the data available.[13–19] All deviations of observed values of S and $\log_{10}N$ appeared to be fairly close to the theoretical values, and the probability theory at first sight seemed to give reasonable agreement with the experimental data; however, if account is taken of the fact that a portion of the deviation equal to some percentage of the stress was certainly due to non-probability causes in the sense previously defined, these same values were found to become actually somewhat small relative to those predicted theoretically. In the case of Monel, for which data were available for fairly high numbers of cycles (of the order of 10^8), the deviation of $\log_{10}N$ was definitely less than 0·42 and consequently it seems that a "probability effect" can definitely be ruled out in this instance. For steel, $\mu_{\log_{10}N}$ was sometimes around 0·42, but also in these cases it is very probable that the entire effect was due to differences from one specimen to another. Steel has an effective fatigue limit before reaching 10^6 cycles, and the observed deviation of S corresponding to this limit should then be zero. It was found, however, that μ_s, either at or before the fatigue limit, was always approximately constant. It therefore follows that the "probability effect" must be practically zero. Similar considerations also applied to all the other materials tested which show fatigue limits, and for which it was observed that the standard deviation of S was independent of N.

For the light alloys tested, in the region between 10^6 and 10^9 cycles, $\mu_{\log_{10}N}$ was of the same order of magnitude as the theoretical value, but here also the major portion of the dispersion was perhaps due to statistical

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differences in the tests. However, it may be that a certain probability effect exists and becomes more evident for extremely large numbers of cycles (above 10^7). In the case of Ergal, for instance, for endurances greater than 10^7 cycles, the deviation of $\mu_{\log_{10}N}$ was appreciably greater than 0·42.

The experimental data available are unfortunately still too incomplete and lack the precise details required to carry out more accurate calculations. Even at this stage, however, it appears possible to conclude with reasonable certainty that the probability hypothesis is not a valid explanation in the majority of cases for the shape of the *S-N* curve for metals and in particular for steels. Only for some light alloys there may perhaps be some " probability effect " at very large values of *N*.

A field in which the probability theory might perhaps be applicable is that of fatigue at high temperatures, where recovery phenomena occur during the tests, and in regard to which, therefore, it may be expected that theoretical conditions obtain to a better degree as regards the equivalence of consecutive cycles for the occurrence of rupture. The fatigue curves of metals at high temperature are, in fact, substantially straight lines with a very small slope in a diagram of *S* against $\log_{10}N$, and it does not seem that a fatigue limit exists even at extremely high numbers of cycles[12]. It may be noted that the probability theory of fatigue also indicates that a fatigue limit does not exist if the distribution of the probability of rupture $P(S)$ is continuous and indefinite. Unfortunately, data on the dispersion in this field are not available.

CZECHOSLOVAKIA

Friction Welding

By J. MANDAUS and J. VIBORIL. (From *Strojirentsvi*, No. 9, 1957, pp. 681–686, 35 illustrations.)

This article describes a method of welding by means of friction-generated heat and gives details of the results obtained with a test set-up on a suitably adapted lathe, together with indications of weld quality and the economics of the process.

FRICTION welding is a new method of welding in which frictional heat is generated by pressing together the two parts to be joined, one part being rotated and the other held stationary. When, after a short period, the material at the interface becomes plastic, an additional pressure (upsetting pressure) is applied and, a few seconds later, relative motion between the two parts is stopped, either by allowing both to rotate together, or by rapidly bringing the rotating part to rest. The basic parameters, i.e., the temperature of the surfaces to be welded and the magnitude of the upsetting pressure, are essentially similar to those applying to resistance or flame butt welding.

To explore the potentialities of friction welding, which appears to have originated in Russia, tests were carried out at several Czech plants and research institutes, using suitably adapted existing lathes, as special equipment for this purpose has not yet been developed. In this connection, it should be understood that, although lathes of robust construction were used for these tests, they were not inherently suitable, as machine tools of this kind are not normally capable of withstanding the high axial loads required in friction welding.

The two types of lathes used in these tests were adapted for welding test rods and tubes of 80 to 100 mm length and up to 24 mm diameter. In one of these types, as shown in Fig. 1, two tailstocks are used, of which the intermediate tailstock holding one of the components to be welded in chuck *A* is provided with hydraulic means of applying contact pressure to the other component, which is chucked in the headstock. A spring, mounted in a telescopic housing, is fitted between the intermediate tailstock and the rear tailstock, the latter being of conventional design. This spring can be compressed by the handwheel on the rear tailstock to a maximum load of 1500 kg, its purpose being to provide upsetting pressure by impact, when the trigger *C* is released. Provision is made to provide different loads, i.e., 300, 700, 1100, and 1500 kg. Relative motion between the two components is stopped by means of a mechanism *B*, which, when released, permits the two components to rotate together. The second type of lathe was similarly modified, but the release mechanism *B* was dispensed with, relative motion between the two components being stopped by switching off the drive motor and applying mechanical braking or even reversal of the motor.

From the results so far available, it would appear that the upsetting pressure should be applied from 0·5 to 3 sec after the peak input power of the lathe has been registered and that the required pressure is probably the same as in resistance butt welding, i.e., from 1 to 5 kg/mm² for low-alloy steels, 5 to 10 kg/mm² for medium-alloy steels, and 10 to 25 kg/mm² for high-alloy steels. Relative motion between the components should be stopped from 0·5 to 3 sec after application of the upsetting pressure. The friction pressure probably does not have a direct influence on weld quality, but it will affect the peak of the friction moment and the welding time. The influence of rotational speed on the process and on weld quality will be determined in subsequent tests. From the tests made to date, it would appear that it is necessary to eliminate the influence of human factors, if welds of uniform quality are to be obtained. The entire operation should therefore be made fully automatic.

Studies of the structure and properties of welds of various combinations of low-alloy materials have led to the conclusion that satisfactory welds can be obtained. Fig. 2 is an example of a weld between a low-carbon steel and a low-alloy Cr-Mo steel, while Fig. 3 shows the structure of the weld obtained. With some of these materials, hardened zones were detected in the weld regions, passing gradually into the base material.

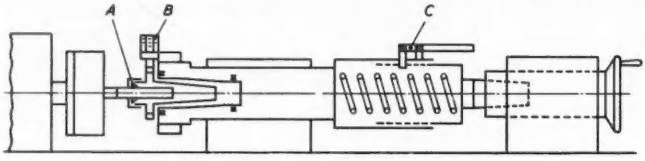


Fig. 1. Adaptation of a lathe for friction welding.

Bending tests have led to the conclusion that all these welds fail in the form of a very brittle fracture at points of high hardness, and this also seems to be indicated by observations of the structure. To achieve satisfactory properties of these welds, further heat treatment is considered necessary, as with other types of welds. Analysis of the microstructure leads to the conclusion that in all cases perfect welds can be obtained, and it is very difficult to determine the boundary between the two welded materials.

In the case of high-alloy materials, high-speed steels, etc., the conditions for formation of perfect welds are considerably more difficult. If materials of equal thermal conductivity are welded, satisfactory welds can be obtained, because the components are uniformly heated. However, if components of markedly different heat conductivity are to be welded, e.g., a high-speed steel to a low-alloy steel, difficulties arise, and, although the joined components may stand up well to operational stresses, the weld cannot, from the point of view of welding technology, be considered to be a good-quality joint. High-alloy materials have a low thermal conductivity, so that their temperature rises rapidly as a result of the heat generated, whereas carbon steels, with their higher thermal conductivity, remove a relatively large amount of the heat. Consequently, such materials as high-speed steels can be heated to temperatures approaching their melting point, while the other material to be welded may still be relatively cold. The weld joint produced in such cases is imperfect. Fig. 4 shows a weld between a low-carbon steel and a high-alloy Cr-Ni steel. Fig. 5 shows the structure of the joint, in which seizure is clearly evident, but not welding.

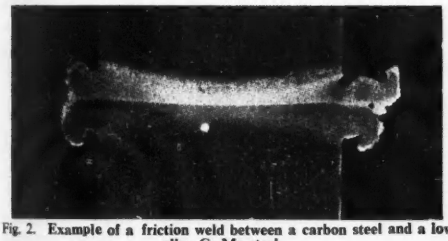


Fig. 2. Example of a friction weld between a carbon steel and a low-alloy Cr-Mo steel.

Fig. 3. Structure of the weld shown in Fig. 2.

On the basis of the tests carried out, it has been concluded that weld test conditions must be so chosen as to correspond with normal operating stresses, a combination of tensile and bending tests and, in some cases, impact tests being considered most suitable. Both types of tests are considered necessary, since seized but not welded material may withstand tensile stresses, yet may be unable to withstand bending stresses.

Insofar as the economics of friction welding are concerned, as only a very narrow zone of the material is affected by direct and rapid transformation of mechanical energy into heat, it is estimated that the power consumption of friction welding is only about 10 to 20% that of resistance welding. Furthermore, as three-phase motors can be used, loading of the lines is more equitable than it is in the case of single-phase fusion-welding units, while load surges in the case of friction welding are at most only 30% of those arising in fusion welding.

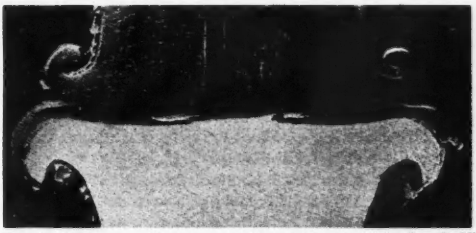


Fig. 4. Friction weld between a carbon steel and a high-alloy Cr-Ni steel.

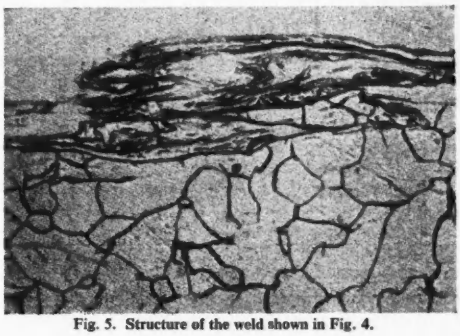


Fig. 5. Structure of the weld shown in Fig. 4.

Naturally, in considering the economics of this type of welding, it is necessary to bear in mind that suitable equipment must be provided. However, although the ultimate aim should be to develop special friction-welding machines, existing equipment can be adapted at relatively little expense, the main requirement being for liberally dimensioned thrust bearings to take up the upsetting pressure, and the provision of the extra tailstock, spring, and release mechanisms, as previously described. It may also be necessary in some cases to provide for increased headstock-spindle speeds (from 800 to 1500 rpm, depending on the diameter of the components to be welded), and the fitting of a motor with a higher rating and possibly also with a flywheel.

In conclusion, it is stressed that, although the technique of friction welding can be adapted to the type of machine used and to the material and diameter of the components, the quality of the welds obtained is variable, owing to the human factor, as previously stated. Consequently, if friction welding is to be introduced without the risk of failures, it is necessary that it be submitted to exhaustive theoretical and experimental tests on the actual components it is desired to produce. Such tests must include rigid mechanical testing and metallographic examination of test welds, to ensure that they are of uniform quality. Furthermore, for every given product, a welding technology giving optimum parameters must be worked out, and it is essential to ensure reproducibility of these parameters. This can only be achieved by full automation.

SWITZERLAND

A Transformer-Oil Expansion Vessel with Rubber Diaphragm

By H. SCHNEIDER. (From *Bulletin Oerlikon*, No. 323, August 1957, pp. 61–66, 10 illustrations.)

THE requirement for maintaining transformer oil in perfect condition is of considerable economic importance, as deterioration of the oil may injure the entire transformer or may drastically reduce its service life. The capital invested in a transformer is about 25 times greater than the cost of the transformer oil, but periodic inspection, reconditioning, and replenishing of the oil is an appreciable item. Moreover, the supply of power to extensive areas depends on the reliability of transformers and therefore on the condition of the oil used.

The difficulties which occurred initially in transformers, arising from ageing of the oil, with the consequent development of high acidity and the formation of oil sludge, have largely been overcome. Oils are now available with reduced oxidizing tendencies and temperature sensitivity, and increasing use is being made of oils containing certain inhibitors for delaying the ageing process. Although it is true that, in service, oils containing inhibitors will age rapidly under appreciable thermal loading, after the inhibitors have been consumed, such inhibitors definitely confer an improvement in ageing resistance, and considerable time elapses before the exhibitor is exhausted.

The disadvantages of a free air space above the oil, as regards the formation of condensate and rusting, can be eliminated by suitable ventilation. Nowadays, transformers with small and medium power ratings up to about 25 kV operating voltage, with a free air space above the oil level, are supplied without reservation for both indoor and outdoor installations, especially if they are not subjected to high thermal loads.

Complete protection of the oil from oxidation and moisture can be achieved by hermetically sealing the space above the oil level. This method has, however, some disadvantages, as the excessive air pressures occasioned by expansion of the oil usually require strengthening of the tank, while in some cases the air space above the oil must be made two or three times greater than for transformers with a free air inlet. The sealed space above the oil level can also be filled with nitrogen, and this is particularly effective in preventing oxidation and moisture.

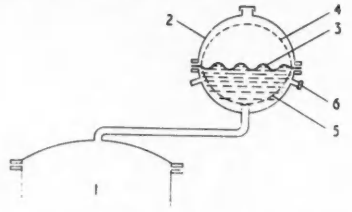


Fig. 1. **Schematic arrangement of oil expansion vessel with rubber diaphragm.**
(1) Transformer ; (2) expansion vessel ; (3) rubber diaphragm ; (4), (5) position of diaphragm at maximum and minimum oil levels ; (6) degassing plug.

The two main disadvantages of transformer tanks with expansion vessels are that the overall height becomes from 10 to 15% greater, and, even more important, the well-known Buchholz protective apparatus cannot be used with these designs. The provision of separate oil expansion vessels represents a considerable advance, as they do not impede fitting of Buchholz apparatus. Transformers with separate expansion vessels can also be protected in various ways by means of nitrogen, but although they serve their purpose satisfactorily, such arrangements are fairly expensive, require considerable space, and necessitate periodic replenishment of the nitrogen.

To overcome the disadvantages of existing methods, a new type of expansion vessel has been developed by Oerlikon, in which, as shown in Fig. 1, the cylindrical vessel consists of two semicircular halves, between which an oil-resistant rubber diaphragm, 2 mm in thickness, is fitted to provide an oil-tight seal. The upper half of the cylinder is used as a cover only, to protect the rubber diaphragm, and the space under the diaphragm is completely filled with oil, the upper space communicating with the outside air. An oil-level gauge is fitted in one of the end-faces of the vessel. At minimum oil pressure, the diaphragm caves in completely and lies on the lower half of the cylindrical vessel, while at maximum oil level it bulges upwards into an approximately semicylindrical shape inside the upper cover. The width of the diaphragm is somewhat greater than the diameter of the cross-section, so as to ensure only small mechanical stresses in the rubber and correspondingly low pressure variations in the oil. A diagram of pressure variations (in cm oil-column) with different filling percentages is shown in Fig. 2.

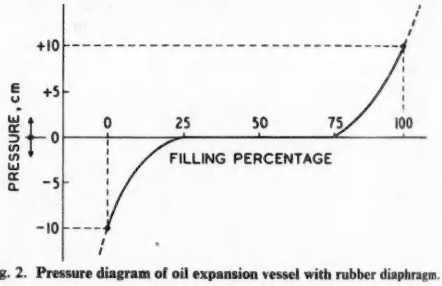


Fig. 2. **Pressure diagram of oil expansion vessel with rubber diaphragm.**

This design is remarkably simple and compact, and its small pressure fluctuations do not affect the construction of the transformer tank. In addition, it ensures complete protection from oxidation and moisture. Other advantages are as follows :—

(1) The oil and hence the solid insulating materials in the transformer retain their original values of electrical strength, and air driers are unnecessary.

(2) The oil, extensively degassed in the initial drying and evacuating process, remains in this condition, with beneficial effects on its electrical strength in service.

(3) The composition of the ambient air is immaterial, so that the expansion vessel is particularly suitable for difficult climatic conditions.

(4) Practically no supervision is required and, after very considerable periods of time, it is sufficient to test a sample of the oil for breakdown strength and to check the condition of the diaphragm through an opening in the protective cylinder.

The first oil expansion vessel of this type has now completed five years of continuous service on a 5000-kVA transformer, during which time no changes have been observed either in the rubber diaphragm or in the electrical strength of the oil. In view of these good results, large numbers of transformers with 50- to 150-kV ratings have been equipped with this new expansion vessel.

The Care and Maintenance of Centrifugal Pumps

By W. Wessing. (From *Der Maschinenschaden*, Vol. 30, No. 7/8, August 1957, pp. 105–113, 18 illustrations.)

Although centrifugal pumps require comparatively little attention, to achieve optimum results it is necessary to take into account operating conditions in the selection of such pumps and to avoid major errors in the general layout of the plant.

Erection and Assembly

Trouble-free running conditions can be achieved only if the pumps are set up and operated by competent personnel. Errors in assembly soon make themselves noticeable through rough running and excessive wear. The alignment at the coupling requires checking, even when the pump and its drive motor are mounted on a common bedplate, as the possibility of distortion of the bedplate cannot be precluded. The foundation bolts should be tightened only after the concrete has had sufficient time to set. The pump should be uncoupled when checking the direction of rotation of an electric drive motor or for testing the overspeed emergency cut-out when a steam turbine is used as the prime mover.

Pipe connections should be designed and laid out so that no stresses are exerted on the pump by the pipework. Deformation, particularly when handling hot liquids, can be avoided by means of expansion members, supports, and anchor blocks. Suction and inlet pipes should be as short as possible, without abrupt changes in direction, and should rise or descend with a continuous slope towards the pump, avoiding horizontal sections in which air or gas may accumulate. The pipe lines should be properly designed for moderate velocities of from 3 to 6 fps.

These considerations are important, particularly when several pumps are connected to a common line. Wherever possible, each pump should have its own suction pipe, so that no air may enter from stationary pumps. Conically tapered sections arranged horizontally should be set up in such a way that their upper contour is horizontal, the centre-line therefore having an upward slope. Pumps with a positive suction head offer the best conditions for reliable operation. For pumps handling boiling liquids, the inlet pressure should be sufficiently high to prevent any evaporation taking place in the pump.

Suction pipes are provided with a foot-valve if the pumps are not of the self-priming type. This valve should be located at a sufficient distance between ground level and the minimum water level, to avoid entry of sand, mud, or air. The suction opening should be designed to avoid any swirl in the intake. The stuffing-box should be provided with a sealing-water arrangement. Isolating valves should be kept fully open during operation and should not be used for regulation purposes.

On the delivery side of the pump, a non-return valve is required for high-pressure heads, especially when several pumps operate with a common delivery. For filling a suction pipe fitted with a foot-valve, it is convenient to install non-return valves with a by-pass. With pipes of considerable diameter and high pressures, stoppage of delivery can cause severe stresses in non-return valves. The casings should therefore be made of high-tensile material, as casing fractures are obviously very serious and costly.

Proper attention should be paid to the inertia effects of the water in long delivery lines, these effects being likely to occur when stopping centrifugal pumps. If the pump speed falls off more rapidly than the water velocity in the line, a drop in pressure can occur at the beginning of the line and this gives rise to pressure waves (with negative and positive reflected pressures), owing to the elasticity of the liquid and the pipe walls, and these surges may reach dangerously high values of pressure. The non-return valves must close before the flow reverses and, in the case of pipes of large diameter, they should be provided with means for adjusting valve closure time. To reduce surge amplitude, a by-pass, controlled by the non-return valve, can be provided, The non-return valve should be carefully inspected and tested for proper functioning. An isolating valve, arranged behind the non-return valve, permits overhaul and testing to be carried out without draining the delivery pipe. Any failure of the non-return valve may be detrimental to the pump and its drive unit because, if there is a reverse flow through the pump, with consequent reversal of the rotation of the pumping set, the pump acts as a turbine and will race. This racing tendency under reversed running conditions is particularly apt to occur with pumps having high efficiencies and high specific speeds, and care should be taken to ensure that reverse rotation at normal speeds will not cause damage. For vertical pumps this applies mainly to the thrust bearing and also to the lubrication system.

Fig. 1. Damage from icing up of the impeller of an axial-flow pump.

If the pumps cannot be set up in locations where there is no risk of freezing, they should be drained completely as soon as freezing conditions are expected. Imperfect closure of the isolating valves will allow water to seep through and freeze in the draining system, so that the pump will fill up gradually. The pumps should therefore be designed so that the water can always be completely evacuated. As an example of what can occur, a case may be mentioned where the water was able to pass through a keyed connection into the impeller; subsequent icing up caused fracture of the cast-steel hollow hub, as shown in Fig. 1.

Commissioning and Maintenance

Centrifugal pumps are liable to damage from foreign bodies, particularly in the first period after being put into service. Fig. 2 illustrates an example of the damage caused to the impeller of a pump, in which large sections

of the vanes were broken off by foreign bodies. Before commissioning the plant, thorough cleaning and rinsing of tanks and inlet pipes are therefore recommended. It is also advisable to provide strainers for the protection of the pump from foreign bodies. The strainer should have a large free cross-section, so as to avoid an excessive increase in resistance. In pipe lines, strainers with a cross-section four times greater than that of the pipe are found most suitable. The inlet pressure behind the strainer should be checked, and the strainer should be cleaned whenever increased resistance becomes noticeable.

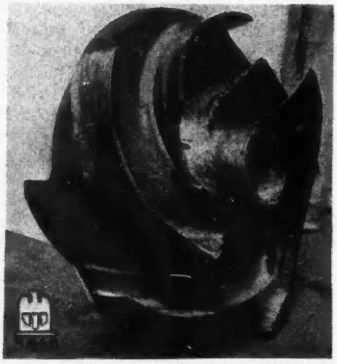


Fig. 2. Damage caused by foreign bodies to the double-inlet impeller of a cooling-water pump.

Before a pump is commissioned, the isolating valves in the suction or inlet line should be fully opened; in addition, it is useful to check the pressure in the suction line. Suction lines with a foot-valve are filled through the by-pass of the non-return valve. For priming, an air-evacuating pump is frequently used. If cooling arrangements are provided, the cooling water should be turned on. The isolating valves in the delivery pipe remain closed during starting, but any starting valves provided should be opened. After reaching operating speed, the delivery valve is opened and set to the required conditions. The hand-starting valve, if provided, is then closed as soon as the minimum flow volume is delivered. Propeller pumps with high specific speeds are started up with an open delivery line, since the power requirement is greatest at zero load. A check is made of stuffing-boxes, lubrication, and oil pressure. When stopping the pump, the isolating valves are operated in the reverse sequence, and the running-out process is observed.

All required operating and maintenance instructions should be displayed at the operating point, and log books or record sheets should be kept by the attendants. Supervision by competent personnel is advisable, particularly for large pumping aggregates. Hourly readings should be recorded for pressures, temperatures, outputs, oil levels, running times, and running speeds, with notes on the axial clearance of the pump rotor and the drive unit and any other observations. Centrifugal pumps not requiring continuous supervision should be periodically checked (daily or after longer periods) as regards quietness, stuffing-box condition, lubrication, and general behaviour.

The stuffing-box should be examined with particular care. The useful life of the packing is increased by smooth running conditions, as rough or eccentric running of the shaft causes hammering on the packing. An elastic packing is required for high running speeds. Soft packings of long fibrous material are preferable but, in special applications, alternate soft and hard packing rings are used. Before inserting the packing, the packing space and the shaft sleeve of corrosion-resistant material should be carefully cleaned. The packing rings are split obliquely in such a way that the ends overlap smoothly, and are then impregnated in a mixture of oil and graphite and fitted so that successive joints of individual rings are at right angles to each other. In order that the stuffing-box may be guided while being tightened up, it should extend sufficiently far into the packing space. Any contact between the stuffing-box and the rotating shaft sleeve will cause overheating and damage to the sleeve. Considerable leakage occurs with a freshly packed stuffing-box but, after a certain running-in period, leakage decreases. The nuts can be tightened up gently until only a slight drip is noticeable. When the stuffing-box provides complete sealing and tends to become hot, the nuts should be loosened. The type of packing to be selected depends on operating requirements.

Lantern rings for sealing water or grease lubrication should be fitted so that they will communicate with the corresponding passages. For hot liquids, suitable cooling is required to prevent high temperatures in the packing; otherwise, the grease in the packing will be rapidly consumed and the packing itself will be destroyed by dry friction. To keep the heat generated by friction at a low value, it is necessary that the protective sleeve around the shaft should have a high-quality surface.

As the stuffing-box is still the component with the lowest service life, designs of pumps without stuffing-boxes have been developed for minimum maintenance. In such applications, the pumps and a "wet" drive unit are built as an integral unit which is subjected to hydraulic pressure. Fully reliable constructions are available, particularly for heating plants. Also, for high pressures (above 150 atm) designs without stuffing-boxes have been built and successfully tested for boiler circulating pumps and for chemical processes. Further development of these pumps may well provide a major contribution to a reduction in maintenance and an increase in reliability.

To dissipate the heat due to friction, water-cooling of highly loaded bearings or the provision of forced lubrication with an oil-cooler is required. When dirty water is used, the cooler should be cleaned at regular intervals. Pumps for hot liquids have a cooling section ahead of the stuffing-boxes and the stuffing-box itself is also cooled. The cooling-water discharge lines should have individual open outlets, so that they are easy to inspect and adjust. If scale deposits build up in the cooling passages, they can be cleaned periodically by rinsing with a suitable chemical.

In centrifugal pumps, any leakage of fluid into the bearings adversely affects bearing lubrication. The shaft is therefore provided with splash-rings which prevent the entry of water or other substances. If the lubricant is contaminated or needs replenishing, the bearings should be thoroughly cleaned before fresh lubricant is added. Rolling bearings, which should be replaced before their service life is exceeded, are filled with grease only up to about two-thirds of their capacity. The life of different greases varies considerably and depends on the type of bearing, running speed, load, and other operating conditions. It is preferable to clean and refill rolling bearings with new grease than to replenish them by adding the extra amount required. When journal bearings have been resurfaced or refitted because of excessive play, the centricity of the shaft in the pump should always be

checked. Oil-ring bearings should be inspected for correct running of the rings, and means should be provided to facilitate observation of oil level and temperature.

Pumps with forced lubrication of bearings have an additional lubricating ring or an auxiliary oil pump for lubrication during starting. It is advisable to incorporate a pressure-control device which allows the auxiliary pump to stop when correct oil delivery is ensured by the main oil pump coupled to the drive.

Some types of pumps, e.g., submerged pumps and deep-well pumps, have water-lubricated rubber bearings. Owing to swelling of the rubber, a comparatively large clearance is necessary, e.g., 0·3 mm for a 10-cm shaft. Water for lubrication is drawn from axial grooves between the wall of the rubber and the rotating shaft, so that a thin film of water is formed. If these bearings are fitted in a pump handling clean water, the latter can be used for lubrication; otherwise, a special clean-water circuit is necessary. However, the quantity of water used can be decreased if the bearing is so arranged that its heat can be dissipated by the main flow of water. For rubber bearings with helical grooves, the direction of the spirals should correspond to that of shaft rotation. Any contact with rubber-dissolving media, such as oil or grease, should be avoided, and the bearing temperature should not exceed 60°C. The water used for lubrication must not leave any deposits on the bearing, to avoid filling up the grooves. It is good practice to install a flow indicator for the water.

Centrifugal pumps are usually directly coupled to their prime movers. The flexible coupling used for torque transmission should not be regarded as a reason for allowing radial or angular misalignment between the driving and driven shafts. Alignment should be checked by means of a dial gauge, and replacement of any rubber elements in the coupling should be made as soon as required. A high rate of wear of these elements usually indicates excessive misalignment, which can cause damage to stuffing-boxes and bearings. Gear-type couplings with continuous lubrication are used for high speeds and powers. Any dirt in the circulating oil is apt to accumulate in gear couplings, which should therefore be cleaned after fairly long running periods.

The regulation of the output of centrifugal pumps is of importance for reliability and economical operation, so that frequent checking and constant supervision are advisable. The simplest regulation is by throttling, but the efficiency of the pump decreases with increased throttling. For axial-flow pumps, throttling is permissible only within narrow limits. The throttling devices, being subjected to considerable stresses, require careful design, as regards flow conditions and materials used in their construction. Operation with discharge valves fully closed should be allowed only for brief periods, to prevent overheating of the pump. For pumps handling boiling liquids, the minimum rate of delivery should always be sufficient to dissipate heat due to friction, and a by-pass can be used for this purpose. Similar means can be employed for pumps with high specific speeds, to avoid unstable pumping conditions.

Regulation of output by varying the pitch of the impeller blades is very effective, and in some respects is even better than speed regulation. However, owing to manufacturing considerations, variable-pitch designs are mainly employed in large-size units. Economical regulation by adjustment of running speed is easily possible if the drive is from a prime-mover. When three-phase electric motors are used, however, speed regulation becomes an expensive solution. If any disturbances are noted in an automatic regulation system, change-over to manual control should be performed immediately and the automatic system put right as soon as possible.

For supervision of operating conditions, the minimum requirement is to fit pressure gauges for both the delivery and inlet pressures, and these should be arranged so that they can be seen simultaneously. Measurements of flow rate and power input are desirable for ascertaining the behaviour of the pump under running conditions; on the basis of these values, efficiency can be evaluated at monthly intervals for large-size units, and any changes can then be investigated.

Typical Causes of Damage

The most frequent types of damage occurring in centrifugal pumps are those caused by destruction of material. Generally, the damage is due to the combined action of several factors, and, in assessing the causes of damage, it is necessary to distinguish between destruction of material resulting from cavitation, corrosion, and erosion by entrained foreign matter.

Cavitation occurs mainly at the leading edges of im-

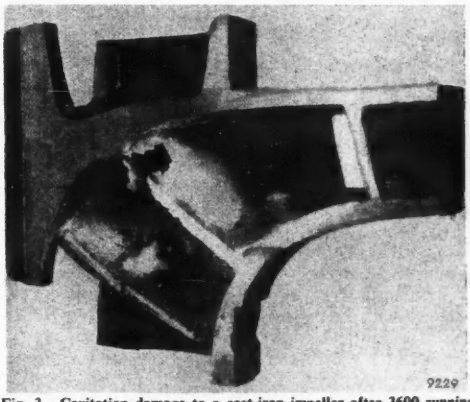


Fig. 3. Cavitation damage to a cast-iron impeller after 3600 running hours, owing to insufficient inlet pressure.

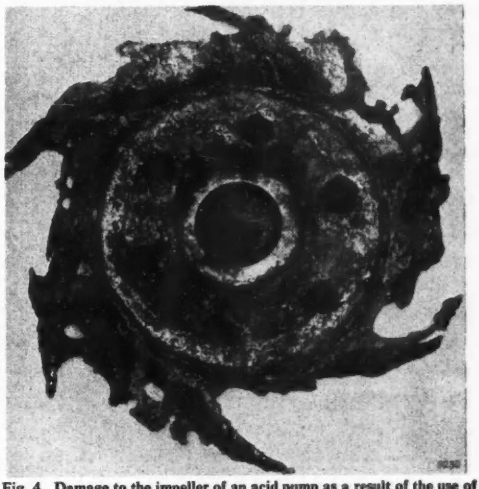


Fig. 4. Damage to the impeller of an acid pump as a result of the use of an unsuitable material.

pellers and the subsequent section of the vane passages, as well as on the adjoining casing (Fig. 3). In multi-stage pumping plant, cavitation occurs only on the first-stage impeller. It also causes a drop in efficiency and irregular running.

To prevent cavitation damage, the formation of bubbles of vapour must be eliminated. Satisfactory operating conditions can be obtained by increasing the inlet pressure. For multi-stage high-speed feed pumps with a low inlet pressure, it is possible to incorporate a slow-running booster pump to obtain satisfactory results.

Pumps for the delivery of corrosive liquids are rapidly destroyed if the materials selected are not suitable (Fig. 4). It should be noted that the liquids may become contaminated during operation ; moreover, pressure and particularly the effect of temperature should also be taken into account. An investigation of the liquid to be delivered, including corrosion tests, usually indicates the types of materials to be employed to fulfil all operating requirements.

When dissimilar metals are employed, attention should be given to the possibility of electrolytic corrosion in the presence of the liquid to be pumped. Chemical corrosion may also occur when handling water, depending on its pH-value. In ordinary water, the pH-value depends extensively on the CO_2 content, and the amount of free oxygen also has some influence. Chemical attack is greatest at positions of high water velocities. The simplest remedy is to raise the pH-value of the water; otherwise, it is necessary to make use of corrosion-resisting alloys. In cast iron, " spongy " corrosion can occur with acidulated water, which mainly attacks the ferritic and pearlitic constituents, the corrosion products remaining at the point where they were generated and covering the graphite and cementite, which are not affected by the attack. Non-uniform chemical corrosion can upset the balance of the component and cause rough running of the pump.

Erosion can occur with liquids flowing at high velocities, particularly when the liquid contains abrasive materials, such as sand (Fig. 5). The sand content of water drawn from wells can be determined with suitable measuring devices and can be eliminated by varying the pump load or by overhauling the well.

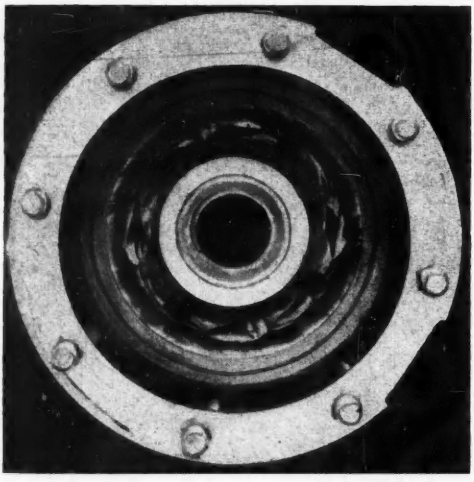


Fig. 5. Damage to the impeller of a submerged pump by abrasion resulting from the entry of sand between the impeller and the casing.

Fig. 6. Damage to a bronze impeller, showing erosion at the exit caused by continuous operation under part-load conditions.

Fig. 7. Wear marks in the discharge cover of a high-pressure feed pump.

Erosion effects can also occur as a result of eddy formation in pumps operating under excessively high or low load conditions for a fairly long period. In such cases, it is necessary to ascertain how and to what extent working conditions deviate from normal running conditions. Axial-flow pumps with high specific speeds are particularly sensitive in this respect. In these pumps, reduced throughput can cause a reverse flow of liquid with considerable eddying near the impeller hub. A secondary flow path is then formed, and a " dead space " is created. The efficiency falls off steeply, and the eddying causes appreciable noise. If the pump is frequently run under the load limit, damage due to high-velocity erosion occurs (Fig. 6). The thrust-balancing arrangement of high-pressure boiler feed pumps, with the extremely high water velocities involved, is exposed to considerable erosive action of this type. High-velocity erosion can be minimized by means of suitable materials.

Erosion due to breaking away of the flow and eddy

formation also occurs in the gap between the impeller and the diffuser, if the entry of water from the impeller to the diffuser is not shock-free. Running at partial loads, particularly with water containing gas or air, is dangerous to the impeller, because eddy formation can release dissolved gases which combine chemical corrosion with erosion. Damage due to erosion is characterized by the fact that wear is in the direction of flow, as indicated in Fig. 7, which shows the discharge cover of a high-pressure feed pump with deep wear marks *b* caused by a flow of water arising from insufficient tightness between the cover and liner. The inner surface of the bore also shows considerable erosion at *c*.

Inspection and Overhaul

The best precaution against trouble is to ensure that centrifugal pumps are inspected at regular intervals. The time between overhauls and the extent to which inspection should be carried out can only be determined from experience. Generally, however, it is found that a period of one or two years can be allowed under continuous running conditions.

All pump components should be examined individually, to detect any alterations in the material, traces of corrosion, and excessive wear. The endeavour should always be to detect damage at its initial stages. Radial clearances between the impellers and the sealing rings require checking. If dismantling leads to results which can be utilized to eliminate the causes of damage or to carry out appropriate modifications for trouble-free operation, the cost of an overhaul is more than covered.

Rough running of centrifugal pumps always denotes some dangerous condition, and in such cases the pump should immediately be opened and inspected in detail. Impellers with peripheral speeds higher than about 16 fps, including their associated rotating parts, should be checked for dynamic balance.

To avoid delays in overhauls, replacements for all main components should be kept in store, particularly components for which relatively high rates of wear are normally expected. Supervision of the amounts of spare parts available is made easier if an index card is kept for each pump, listing the components available in the stores. The index cards should also contain any other essential data on the centrifugal pump, since the name-plates, etc. provided by the makers do not always give sufficient data on the type and performance of the machine.

Although overhauls are generally carried out by the user's personnel, it is recommended that a specialist from the pump manufacturers be consulted for complicated designs. The overhaul of submerged pumps is best left to the manufacturers. If no difficult operating conditions occur, it is advisable to overhaul pumps after 10,000 running hours.

U. S. A.

New Nodular Cast-Iron Welding Rods

By R. O. Day, J. S. Synder, and H. V. Inskeep. (From *The Welding Journal*, Vol. 36, No. 9, September 1957, pp. 410s–414s, 8 illustrations.)

Because of its interesting mechanical properties, nodular cast-iron is proving to be a very valuable material to the foundry industry. While the bulk of this material will continue to be used for casting complete units, it also shows promise as a material from which cast components can be made for assembly by welding.

Previous reports on the welding of nodular iron with nodular-iron filler metal have, on the whole, been pessimistic. The use of other filler metals has been unsatisfactory with regard to tensile strength, freedom from fissures, and colour match.

In order to overcome these difficulties, work was therefore undertaken to discover a method of making a nodular iron which could be used as a filler metal. As a result, a welding rod has been developed which will produce welds in the U.T.S. range of 50,000 to 70,000 psi and with elongations in the range of 5 to 10%, both properties in the as-welded condition. It can be used both with oxyacetylene and gas-shielded tungsten-arc welding.

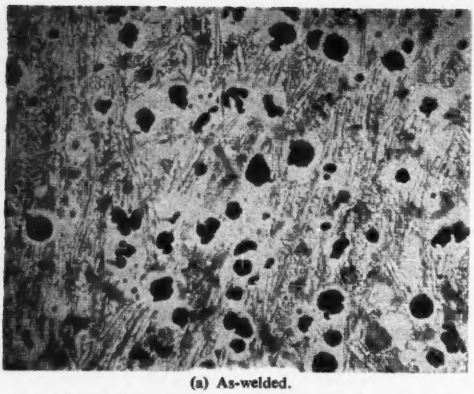
Major controlling factors when welding cast-iron are welding technique and the chemistry of the iron. Oxy-acetylene welding techniques produce a very satisfactory weld in either grey or nodular cast-iron. Improper techniques can very easily produce a hard and brittle material in the weld and in the immediately adjacent heat-affected zone. However, proper manipulation of the welding flame preheats the area surrounding the weld and allows heat to penetrate into the base material, thus preventing the formation of hard and brittle material. This method of control appears to be easier in the welding of nodular iron than in the case of grey iron.

When used with incorrect welding techniques, grey-iron welding rods, regardless of chemistry, can produce a deposit that is harder than desired. Even with good chemistry and correct techniques, it is difficult to keep hardness at a desirable level. Although a fully ferritic iron rod may deposit largely ferritic weld metal with a reasonably satisfactory hardness, other mechanical properties, including strength of the deposited metal, may be unsatisfactory.

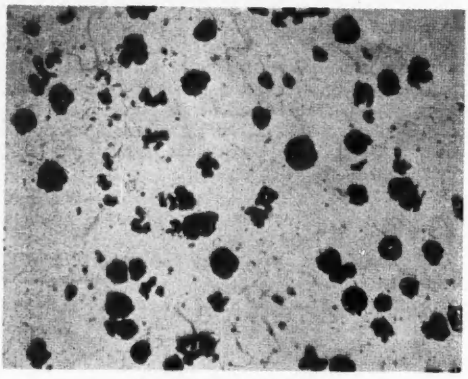
When welding nodular cast-iron, the use of a suitable nodular-iron welding rod appears to create the most desirable combination and will meet the major weldment requirements, i.e., a fully nodular weld without post-heat treatment when deposited by normal oxyacetylene cast-iron welding technique, a weld having a Brinell hardness of 200 or under, a weld deposit having desirable mechanical properties, and a weld deposit having an excellent colour match with the surrounding base metal. The basic chemistry of the new rod is similar to that of the general run of unalloyed nodular iron, except that cerium rather than magnesium is the nodulizing agent.

Laboratory Test Procedure

In studying the mechanical properties of the weld metal deposited by this rod, all-weld-metal test samples were used, with the exception of those for bend tests. Welds were prepared by joining cast-iron plates, 11 in. × 4 in. × 1 in. thick, bevelled to an included angle of 90 deg. All-weld-metal tensile and unnotched Charpy impact specimens were prepared from each weld. Because of the specimen length necessary for suitable bend



(a) As-welded.



(b) After annealing at 1600°F.

Fig. 1. Microstructures of gas tungsten-arc weld made with a nodular-iron welding rod.

tests, specimens had to include the base material on both sides of the weld. However, the bending action was centred entirely in the weld metal. Two types of cast-iron plates were used—a fully pearlitic grey-iron plate and a commercial nodular-iron plate (also pearlitic). Both the grey and nodular-iron base materials represented actual production irons.

Although this nodular-iron rod was designed primarily as an oxyacetylene welding rod, it was believed desirable to obtain some data on arc welding of the material. Samples were prepared, using gas tungsten-arc welding on plates preheated to 1100°F. Initial efforts were made to complete these arc welds using multi-pass procedure. However, in practically every case, cracking occurred either in the heat-affected zone or in the weld metal, or in both. As a result of this experience, a special long-arc technique was developed, and the welding proceeded with the long arc in a manner which closely resembles oxyacetylene technique. Mechanical tests were made only after annealing the arc welds. No effort was made to use these rods as covered electrodes for open-arc welding.

Most of the oxyacetylene welds were made without preheating the plates, because preliminary tests indicated that nothing was to be gained from preheating. Mechanical tests were made on samples in the as-welded condition, stress-relieved at 1100°F and fully annealed at 1600°F.

Test Results

Fig. 1 illustrates the structure of a typical gas tungsten-arc weld made with nodular-iron welding rod before and after annealing. The as-welded structure reveals a considerable amount of nodular graphite surrounded by a ferritic matrix high in free-carbide content. Hardness readings over this area range from 35 to 45 Rockwell C. With the same weld material, annealed at 1600°F, the rather hard carbide-bearing matrix is transformed into an almost completely ferritic matrix containing nodular graphite. The hardness readings over this area have averaged 90 Rockwell B.

Table I. Mechanical Properties of Gas Tungsten-Arc Welds.

Ultimate Strength, psi	58,000
Yield Point, psi	39,000
Elongation, % in 2 in.	7·5
Bend Elongation, % in 1 in.	15·0
Impact Resistance, ft-lb	24·5

An interesting set of tensile and elongation figures (see Table I) resulted from mechanical tests on a gas tungsten-arc weld after it was annealed at 1600°F. Because of the high hardness of the as-welded electric welds, it was not possible to machine mechanical test specimens. A bend through 48 deg. and a bend elongation of 15% in 1 in., however, indicate the very excellent mechanical properties which can be obtained from a gas tungsten-arc weld with the nodular-iron rod, if the weld can be annealed.

The microstructures of three oxyacetylene welds are illustrated in Fig. 2 in the as-welded, stress-relieved, and fully-annealed condition. The areas shown are approxi-

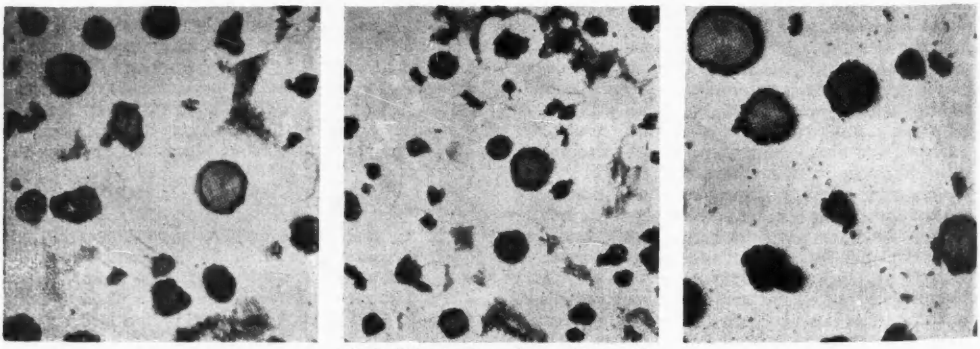


Fig. 2. Microstructures of oxyacetylene welds.
(a) As-welded ; (b) stress-relieved at 1100°F ; (c) annealed at 1600°F.
For mechanical properties, see Table II.

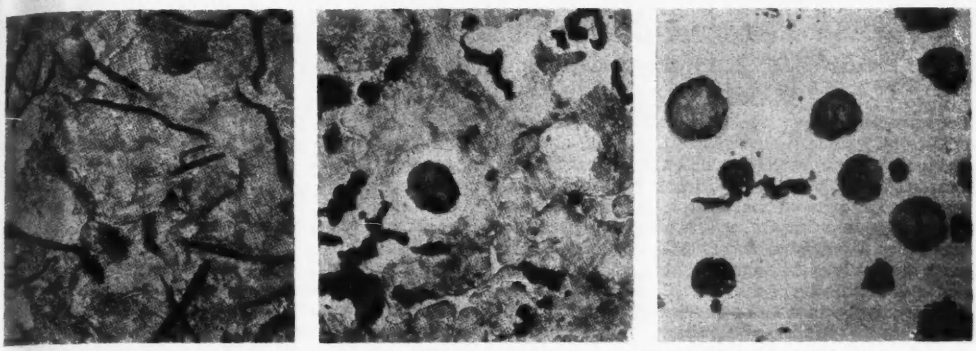


Fig. 3. **Photomicrographs of a sample containing a small amount of pearlite-grey-iron base material and some weld-junction area.** (a) Pearlite-grey-iron base material ; (b) weld-junction area ; (c) all-weld metal.

mately at the centre of the weld and are, without a doubt, all-weld-metal samples. One would not expect to see much difference in the microstructure between the as-welded and the stress-relieved material, nor any great difference in mechanical properties. This is illustrated in Table II. The fully annealed sample shows the expected drop in tensile properties and an appreciable rise in elongation. The bend elongations are also of interest.

TABLE II. MECHANICAL PROPERTIES OF OXYACETYLENE WELDS

	As-welded	Stress-relieved, 1100°F	Annealed, 1600°F
Ultimate Strength, psi	67,000	76,900	66,200
Yield Strength, psi	54,300	60,700	47,400
Elongation, % in 2 in.	3·5	6·75	12·5
Bend Elong., % in 1 in.	14·0	15·0	18·7
Impact Resistance, ft-lb	77·0	79·0	66·5

Fig. 3 illustrates an interesting condition which was revealed in one of the test specimens. For some reason, when this particular specimen was machined from the weld, an error was made, so that a small amount of grey base material, together with some weld-junction area, was included in the supposedly all-weld-metal sample. The photomicrograph in Fig. 3a shows the structure of the pearlite-grey-iron base material. Fig. 3b shows the weld-junction area, with some nodules and a considerable amount of broken-up flakes in what is frequently referred to as a " hot-dog " structure with a rather high percentage of pearlite matrix. The photomicrograph in Fig. 3c shows the structure of the all-weld metal with nodules surrounded by a ferritic matrix. Under tensile tests, this specimen failed at an ultimate strength of 55,300 psi. Elongation was negligible. The ultimate strength of the grey-iron base material was 46,500 psi. From the high failure strength of this test specimen, it is evident that the bulk of the strength was imparted by the nodular weld metal until this comparatively ductile material reached its elastic limit. The stretching of the nodular iron caused the break in the comparatively brittle grey-iron material. Thus, when elongation started, final rupture came almost immediately. The cross-section of this specimen consisted of approximately 5% grey-iron, 15% weld-junction material, and 80% nodular weld metal. This indicates that a great deal of dependence can be placed on a good nodular-iron weld, even though mixed with areas of the less ductile types of iron; also, as long as the yield point of the ductile iron has not been reached, it will retain the load for the composite mixture without failing. However, as soon as the yield point of the nodular iron is reached, failure can be expected immediately.

POTENTIAL APPLICATIONS

One can only speculate on the uses to which a rod of this type can be put. Present belief is that the vast bulk of the material will find use as a filler material for the weld-repairing of nodular iron castings. However, there is no reason why the same rod should not be equally acceptable for weld-repairing high-strength grey-iron castings. While there has been no opportunity to try it, the possibility exists that a rod of this nature could also find use for the welding repairs of pearlitic malleable-iron castings.

The rod also has excellent possibilities as a material of components of nodular cast-iron. If the fabricated assemblies are small enough to be annealed completely, this particular rod should prove an excellent material for this purpose. However, even in the as-welded condition, the mechanical properties of such welds indicate the usefulness of this material when annealing or other post-heat treatments are impossible. Where annealing is impractical, it appears that the assembly should be made by the oxyacetylene welding method, unless it is a type of structure in which some embrittlement of the heat-affected zone and a low ductility can be tolerated. Where annealing is possible, it is entirely probable that either oxyacetylene or electric welding can be successfully used as a means of fabrication.

CONCLUSIONS

The data presented here have shown that a nodular-iron welding rod of suitable chemistry, using proper oxyacetylene welding techniques, can form a weld-metal bead of a fully nodular ferritic iron structure. Its mechanical properties will be acceptable for most applications in the as-welded condition. When annealed, its tensile strength is reduced but ductility is increased.

When welded by the gas tungsten-arc process, the as-welded deposit is hard and difficult to machine. Annealing at 1600°F produces a fully nodular and ferritic material with good tensile strength and ductility. When welded with good oxyacetylene techniques, no hard constituents can be found in the weld metal, weld-junction material, or heat-affected zone of the base material. Gas tungsten-arc welding produces hard constituents in the weld metal and in the heat-affected zone. However, annealing completely eliminates such constituents.

At the present time, the rod has been made only on an experimental or pilot-plant basis. It is expected that techniques used to produce the experimental rod can easily be adapted to production operations.

ITALY

Sintered Materials for Friction Elements

By I. Ferraro and E. S. Sgambetterra. (From *La Metallurgia Italiana*, No. 8, August 1957, pp. 581-586, 5 illustrations.)

Conventional linings for brakes and friction elements are basically made from mixtures of rubber, asbestos, and synthetic resin, with the addition of other substances intended to confer improved friction properties. Such materials are quite efficient up to service temperatures between 250 and 280°C, but cannot be used at higher temperatures, owing to decomposition of the binding medium and the rapid decrease in the coefficient of friction with destruction of the material. To overcome this difficulty, brass, bronze, or aluminium mesh has been incorporated, together with asbestos, in the binding medium, resulting in increased wear resistance, though decomposition of the organic binder is still not eliminated. For heavier duties, in which the surface temperature of the parts subjected to friction may reach from 500 to 600°C, it has been found necessary to direct research towards inorganic materials obtained by sintering. The production of sintered metal linings is similar to that used for self-lubricating bearings, filters, etc., but certain differences in procedure are necessary, owing to the characteristic shape of these parts.

Composition of Sintered Friction Elements

Sintered friction elements are generally compounded of copper-tin base materials, with the addition of metallic and non-metallic substances suitable for correcting the final characteristics of the products. From 60 to 80% copper is used, according to requirements; about 70% of the copper powder used should have a particle size of less than 45 microns, and the remaining 30% not more than 100 to 120 microns. The particle shape should be dendritic, so as to ensure optimum mechanical bonding during compacting operations. The normal admixture of tin to the copper is 10%. Higher percentages produce greater hardness, which may in special cases be useful because of better wear resistance, but the coefficient of friction is reduced. Low percentages of tin produce very soft linings, forming spots on the friction surfaces and giving rise to unequal wear. Iron is added in a proportion of 5 to 10% by weight and serves to increase the coefficient of friction and wear resistance of the material.

A pure bronze matrix will prove unsatisfactory with regard to wear resistance, friction temperature, and tendency to warp. These disadvantages have been eliminated by the addition of lubricants (generally of the solid type). Thus, because of its insolubility in copper, lead remains incorporated in the bronze matrix, so that its lubricating effect will be proportional to the fineness of its dispersion. An addition of from 5 to 14% lead exercises a beneficial lubricating effect during compacting operations, and at temperatures above its melting point produces a fluid film with fairly satisfactory lubricating properties. In addition, lead promotes smoothness of action during application of friction, thus tending to avoid vibration. Graphite is added in the proportion of 6 to 12% to integrate the lubricating properties of the lead at low temperatures and to diminish the tendency of bronze to warp.

In addition, from 2 to 7% of very finely comminuted non-metallic substances, e.g., silica, alumina, and asbestos, are added to increase the coefficient of friction. However, these substances produce increased wear and should therefore be added in as small amounts as possible, though it should be noted that very slight variations in the percentage of these ingredients can produce a marked effect on the coefficient of friction.

By suitable variation of the composition of the powder mixture, linings may be produced with friction coefficients ranging from a minimum of 0·15 to a maximum of 0·50. Furthermore, the coefficient of friction of sintered materials is relatively stable and can be confined within very narrow limits, as distinct from conventional linings of asbestos, rubber, and synthetic resin, in which the coefficient of friction varies greatly with changes in operating conditions, i.e., speed, pressure, and temperature.

In some cases, the lining may, if desired, be impregnated with a liquid or semi-liquid lubricant, with a view to diminishing wear and ensuring smooth starts. However, it should be understood that impregnation with such a lubricant is useless if the temperature produced is so high as to affect the stability of the lubricant itself.

Manufacture of Sintered Friction Elements

The manufacture of sintered friction elements may be divided into two stages, i.e., the first stage of preparing the powder mixture, which is similar to that used in other powder-metallurgy fields, and the second stage, which comprises compacting and sintering, and which uses different techniques because of the large areas to be treated.

The powder mixtures are cold-pressed in steel moulds under pressures of about 12 to 19 tsi. Filling of the mould cavity is usually effected by hand, using weighed amounts of powder mixture. In the case of small parts, e.g., washers, discs, etc., automatic presses may be used. Because of their porosity, their high non-metallic content, and their narrow cross-section, the compacts do not possess sufficient mechanical resistance and must be brazed to steel supports, brazing and sintering of the element usually being carried out simultaneously. Belt-type furnaces are usually employed for this operation, sintering being effected at a pressure of from about 120 to 180 psi in a controlled atmosphere.

To ensure perfect brazing, the steel supports should be completely deoxidized. A film of suitable material (a copper film of 0·02 mm gives the best results) is then deposited, preferably electrolytically, on the surface of the support, so as to permit initial diffusion. When the friction elements are in the form of discs or plain sectors, they are packed, together with the corresponding steel supports, in stacks and put into the furnace. To avoid brazing one element to another, inert substances, such as graphite, mica, and talc, are interposed between each element. The heat-treatment operation is usually effected for a period of 30 to 40 min at between 750 and 850°C.

A recently patented method of production of small and thin friction elements (with a friction-layer thickness of 0·1 to 0·4 mm) involved the spraying of an air-drying varnish on the steel discs or bands (previously deoxidized and copper-treated), the powder mixture being allowed to drop onto the surface before the varnish has dried. The solvent is then evaporated in a suitable oven, and any excess powder not retained by the varnish is removed, so that only a thin layer of powder mixture remains on the steel support. This operation may be repeated as often as necessary to obtain the required thickness, after which heat treatment is carried out in the usual way.

Electro-Acoustic Oil-Pressure Detector for Fault Detection during Impulse Tests on Transformers

By B. GÄNGER. (From *The Brown Boveri Review*, Vol. 44, No. 8, August 1957, pp. 336–342, 8 illustrations.)

TYPE impulse-testing of transformers is now widely accepted, particularly for large units for high operational voltages. Such tests involve voltage impulses, of the form 1/50, which have a predetermined amplitude and polarity and which are applied to the line ends of the windings, the other ends and the secondary windings being earthed. Chopped-wave tests with increased peak-voltage values are also applied, but these are always followed by a full-wave impulse.

One method suggested by Hagenguth in 1944 for detecting failures and thereby assessing test results reliably has proved very satisfactory. This method involves the inclusion in the oscillograms (in addition to the voltage at the line end of the winding) of the impulse current at the earthed end of the winding, a fast-sweep oscillograph being employed for this duty. The test has succeeded when the test-impulse wave shapes revealed by the oscillograph do not differ one from the other and when, moreover, apart from the increased amplitudes of the curves according to the increase in voltage, they do not differ from the reference impulses with reduced voltage. Experience has shown that, with Hagenguth's method, if properly applied, faults likely to develop during the impulse test are unmistakably prominent in the cathode-ray oscillogram, and even the most insignificant damage to the winding can be detected in a reliable manner.

Nevertheless, such a method of fault detection, ensuring the registration of the minutest details of processes lasting for only millionths of a second, naturally involves the use of costly measuring equipment and trained staff for operating and evaluating the oscillograms. Furthermore, the inclusion in the oscillograms of irregularities, which can be traced to deficiencies in the measuring circuit or possibly to a small spark occurring in some completely harmless position in the transformer, is by no means uncommon. Although disturbances of this nature have an unfortunate habit of also appearing in the cathode-ray oscillograms, they must not be regarded as a sign of insulation break-down, and a certain amount of experience is necessary before it is possible to distinguish between these disturbances and actual break-down; otherwise, there is a real danger of condemning a perfectly good transformer.

THE BROWN BOVERI ELECTRO-ACOUSTIC METHOD

After several years of development work, a new method of objectively detecting impulse-test faults in oil transformers has been evolved by Brown Boveri. The prerequisite in this case was the knowledge that every fault caused by impulse-testing oil-insulated windings can be traced to sparking in the liquid dielectric, and that the pressure fluctuations thereby initiated can be converted without much trouble to equivalent electric pulses which, after amplification, are capable of registration. In principle, the electro-acoustic indicator developed comprises a probe immersed in oil, an amplifier connected in series, and an oscillograph for showing and possibly registering the oscillations. The latter do not occur in synchronism with the electric voltage impulse during extremely brief periods, but subsequently, and at the greatly reduced rate of sound propagation in the liquid medium, and with reflection from the boundaries and overlapping of the acoustic wave trains. In these circumstances, a fast-sweep oscillograph is by no means necessary; a small hot-cathode or electromagnetic oscillograph is quite adequate. The complete equipment is therefore light, cheap, and quickly prepared for service.

The probe comprises an electromagnetic microphone connected in series with a matching transformer. Apart from its robustness, its low-resistance output is advantageous, insofar as capacitive disturbances are kept almost completely remote from the amplifier; furthermore, the capacitance of the lead does not reduce the measurement value. As a protection against external magnetic fields, the probe is surrounded by an oil-tight steel casing. The fact that the voltage supplied by an electromagnetic system is not in direct proportion to the acoustic pressure, but to the diaphragm speed, is not significant, since in any case only higher-frequency oscillations are evaluated. Other kinds of microphones, such as carbon, capacitor, and electrodynamic microphones, have, for various reasons, proved to be less suitable, while piezoelectric microphones are unsuitable because of the comparatively high temperature involved.

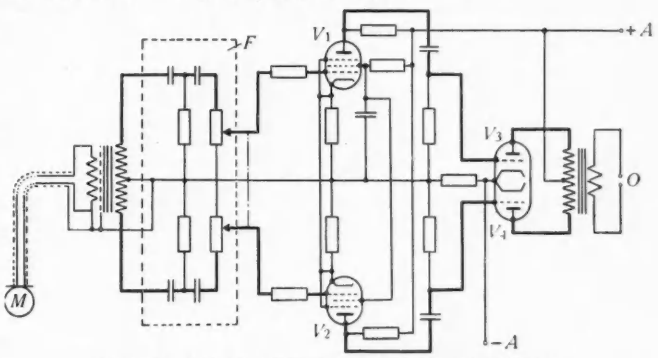


Fig. 1. Circuit diagram of the electro-acoustic oil-pressure detector.

The basic circuit diagram of the detector is shown in Fig. 1. The probe, i.e., the microphone *M*, which is immersed in the transformer oil and which can readily be introduced through the filling connection, is connected with the amplifier set by means of a shielded cable. The signal arrives via a filter *F* at the symmetrically constructed two-stage amplifier with resistance amplifiers V_1 and V_2 in the first stage, and a push-pull output stage V_3, V_4. The oscillograph loop *O* is connected to the matched output transformer. *A* is the anode voltage. As the result of amplifier saturation, the output current remains below the prescribed maximum value, even in the event of severe over-control, and the loop deflections are thus limited in both directions. On the other hand, even the feeblest acoustic waves are registered in an extremely sensitive manner.

The process is recorded by allowing the beam of light to play on sensitized strips of paper arranged round the periphery of a drum. The latter, 6·5 cm in diameter and driven by clockwork or by an electric motor, rotates at approximately 0·5 m/sec, so that the zero line is recrossed 2·5 times per second. If it is desired to avoid intense blackening and a widening of the base line, owing to numerous recrossings, the impulse generator must not operate with self-firing, but by means of a superposed impulse trigger at a well-defined instant. The shutter of the registering device is then opened either by hand or automatically by the trigger shortly before the selected instant of test, and is closed again immediately after the impulse. The movement of the beam can also be observed on a ground-glass plate while the photograph is being taken, incidentally without registration in the direction of the time axis. Thus, the result of the test is known without waiting for the photographic film to be developed.

A light mechanical blow against the tank wall produces a fairly regular train of vibrations, in which unduly high frequencies are not represented. Sparking in the oil evinces a wider frequency spectrum. Even with the shortest flash-over distance, the vibration of the oil caused by the extremely feeble noise of the spark is shown unmistakably. Surrounding the spark gap with insulating material has only an insignificantly detrimental effect on the registration ; moreover, an unfavourable position with respect to the probe, or the insertion of partition walls or solid bodies between the two, have equally little influence. Even when the entire mass of iron core and winding, also a long distance through oil, are located between the microphone and the spark, the registration is absolutely unambiguous. It is, however, not possible by altering the position of the probe to confine the position of the fault or at least to establish it approximately. The process is basically unsuitable for this duty. The propagation of the sound waves in all directions and their multiple reflection from the active part and the tank walls disperse the sound energy throughout the entire volume of oil. The flow of sound is thus rendered directionless, and the sound is equally distributed.

Occasionally, the cathode-ray oscillogram contains signs of faults which do not originate from the windings, but from a defect in the measuring circuit. Thus, from time to time, high-frequency impulses may be observed, superposed on the impulse-current curve on the earth side, or an irregularity in the measured value, with a sudden jump to a different level, followed mostly by an early return to the original shape, but this does not affect the fundamental character of the method. With transformers for low rated voltages, permanent magnetization of the iron circuit has been observed, as a result of impulse magnetization, so that the current curves in the cathode-ray oscillograms of successive impulses are displaced to somewhat higher values, and therefore no longer coincide, although up till this instant the insulation did not sustain damage. In every one of these cases the detector registered a fault-free curve, demonstrating that the irregularity indicated by the cathode-ray oscillograph must not be attributed to faulty insulation, but primarily to the testing circuit, and that, till then, the transformer had withstood the test. The cathode-ray oscillogram definitely furnishes valuable details of the impulse wave-form and is indispensable for predicting the apparent break-down position ; similarly, the detector also possesses great advantages. In the case of distribution transformers, which do not cause a radical change in the impulse form when connected, and thereby enable front and half-value times to be calculated in a simple manner from the characteristic values of the impulse circuit, it is considered in every way admissible to work with the detector alone, without employing the ponderous cathode-ray oscillograph, which adds to the cost of the test.

In one quite special case, i.e., the impulse testing of a winding together with a voltage-limiting protective device, the detector is considered to be absolutely indispensable. A solution of this nature is sometimes sought, for example, for power transformers having control on the line side, which couple two supply systems whose operational voltages differ only slightly from each other. If the protective device operates during the test, the effect with respect to the transient phenomena in the transformer is similar to that of an actual fault in the winding, and also causes changes in the measured electrical values which can hardly be distinguished from a fault. The extent to which the introduced short-circuit manifests itself in the following inductive phenomena is dependent on the magnitude of the diverted current and thus on the characteristics of the non-linear elements and the internal resistance of the winding.

In the case of transformers having overvoltage protection incorporated, the conventional mode of fault detection approaches or even oversteps its dependable working range. It is quite feasible for small winding faults to remain concealed behind the changes in the curve which emanate from the protective device. Even when, in order to ensure a closer check on the expected irregularities, the impulse voltage is increased step by step up to the full test value, the cathode-ray oscillograms alone no longer provide a reliable basis for judging test results. The degree of unambiguous accuracy needed is assured, even in this special case, by employing the oil-pressure detector.

Insofar as chopped-wave tests are concerned, these have admittedly assumed some importance in recent years, the object being to simulate as many as possible of the stresses which the transformer is likely to encounter in operation. Although considerable doubts have been and continue to be raised regarding this method of test, it should be mentioned that the difficulties opposing a definite statement concerning the results of the chopped-wave tests, based solely on the cathode-ray oscillogram, do not exist with the detector process, or at the most only in greatly reduced measure. The insulation failure caused by the abrupt voltage surge continues to be initiated by a spark in the oil and is therefore the originator of the pressure impulses. The only point is that the converted energy in the discharge path is usually somewhat smaller, owing to the break-down of the driving voltage at the gap used to chop the wave, and the consequently far shorter duration of the stress. Experience shows that, with a full wave, the failure spark takes a long time to collapse, while in the case of chopped waves it can very quickly break again ; however, the longer spark duration does not lead to any very considerable increase in the amount of energy converted. As with residual voltage, the current in the discharge path also decreases rapidly with the discharge of the capacitances involved, back to small values. Thus, with sound recording by means of the detector, only certain degrees of difference are to be expected, but none of magnitude.

With regard to the shorter duration of the process, there are no essential disadvantages to be feared when the detector process is employed. On the other hand, it is rather more difficult to prevent the oscillogram from being distorted by the inclusion (with disturbingly large

amplitudes) of the noise, already painfully loud at the high test voltages, which emanates from the gap used for chopping the waves, located near the test object. For tests with full-wave impulses, it has been found that the most suitable degree of sensitivity is achieved when a barely discernible deflection is caused by tapping lightly on the tank. In the case of tests with chopped waves, on the other hand, the flash-over at the gap used to chop the wave should be just recognizable by a slight twitch of the light on the ground-glass plate (the test object here is obviously disconnected).

During the course of chopped-wave tests, the detector oscillogram registered a failure in every case in an unmistakable manner, not only when the test was arranged with that intent, with weak spots introduced into the winding artificially, but also when winding faults developed during the test. The main obstacle opposing an unequivocal judgment of the test result is thus eliminated. It is quite clear, when the detector is employed, that there is no justification for the frequent requirement concerning accurate chopping with respect to time of the reference and test impulses.

U.S.A.

Aluminium Honeycomb Cores as Impact Absorbers

When a collision takes place, e.g., between an automobile and a telegraph pole, the amount of damage sustained is a direct function of the deceleration rate. If deceleration occurs virtually instantaneously, all the kinetic energy of the moving body is likely to be converted into destructive action. On the other hand, if deceleration takes place over even a brief period of time, allowing the mass of the moving body to come to a stop, the destructive impact forces, i.e., the *g*-load, is very greatly reduced.

This, then, is the theory behind the use of all shock-absorbing materials, which are intended to lengthen the period of deceleration by allowing the protected object to shift slightly while coming to a stop. Based on practical tests and extensive research,* it has now been established that aluminium honeycomb cores constitute an almost ideal material for the absorption of impact energy, inasmuch as they not only collapse in accordion fashion, as shown in Fig. 1, with progressive folding from one face to the other, but also they absorb impact energy at a nearly constant rate. As a result, by presenting a constant resistance during total deformation, they enable deceleration forces to be held at a constant *g*-load just below the damage level, as distinct from most conventional padding materials, which deform in non-linear fashion, the higher the deformation the higher being the resistance to further deformation.

The constant resistance to deformation demonstrated by a honeycomb nearly duplicates the characteristics of an ideal shock-absorbent material. This has been shown by stress-strain curves for typical honeycomb samples, in which a high initial peak, representing the inherent characteristic strength of the core before failure is initiated, is followed by a flat section which is proportional in duration to the depth of the core sample, and during which the accordion action takes place. A final, high plateau occurs after the absorbent core material has been completely crushed and is effectively a solid block of aluminium. The initial high peak is undesirable, as it may cause a momentary *g*-load beyond design limits. It has, however, been found by Hexcel that, by densifying the honeycomb core cells with a foamed plastic, it is possible to increase the stress/strain ratio and still retain the flat-curve response of the deformation curve. In this way, the linear deformation characteristics of the honeycomb can be applied to cases where higher *g*-loads can be tolerated. Thus, for example, aluminium, with ⅛-in. cells of 0·0015-in. wall thickness, has a crushing strength of about 350 psi, whereas the crushing strength of a similar core filled with plastic foam is increased to about 2500 psi.

Protection from impact damage naturally depends on the depth and area of the honeycomb buffer. For example, an automobile striking a solid brick wall at 60 mph may be subjected to *g*-values of several hundred. An 8 sq ft honeycomb panel of only 1½ ft thickness, permitting the car to stop in a distance of 1 ft, would, however, reduce the *g*-load to a more tolerable value of 30 and, although this impact load is still too high for safety, it would at least offer a chance of survival. Doubling the depth of the honeycomb would give rise to a very much greater reduction in damage due to impact. In this connection, investigations into the use of honeycombs for promoting the safety of automobiles are now under way. One application, for instance, might be the use of strong, narrow honeycomb panels or a series of cylinders in an expendable shock-absorber behind automobile bumpers. As an additional safety measure, thin panels might be used beneath a suitable covering as dashboard crash-panels.

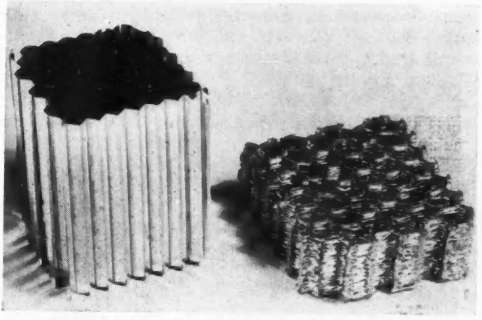


Fig. 1. Effect of impact on an aluminium honeycomb core.

Another obvious and important application would be in industrial packaging. Much of the work on the energy-absorbing characteristics of honeycombs has been in conjunction with the design of pallets for emergency air drops. Industrial crates and packages are not subjected to the same severe impact, but accidental and expensive drops and jars can occur during shipping and storage. The problem has been that these do not occur frequently enough to warrant excessive over-design of the package, even though the total cost due to damage, over a period of time, may be very great.

Other potential uses include crash-helmets, barriers on aircraft ground runways and carriers, and mounting panels for electronic hardware. In fact, any instance where high *g*-loads can cause destructive damage creates a possible application for honeycomb shock-absorbers.

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JAPAN

Measurement of Magnetization and Magnetostriction of Ni-Co Alloys during Magnetic Annealing at High Temperatures

By H. Masumoto, H. Saitô, and M. Takahashi. (From *The Science Reports of the Research Institutes, Tôhoku University*, Series A, Vol. 9, No. 4, pp. 293–308, 10 illustrations.)

Magnetostriction is undoubtedly the most useful of those factors which are indispensable for clarifying the mechanism of magnetization. However, although magnetostriction at room temperatures has been studied in the case of a number of ferromagnetic metals and alloys, very little work has been reported in connection with magnetostriction at high temperatures, mainly because of the difficulties involved in measurements of magnetostriction at elevated temperature. These difficulties have been overcome by means of the special equipment described in this paper, as it enables measurements of magnetization and magnetostriction to be effected simultaneously and accurately at high temperatures.

The alloys used in the course of this investigation were prepared from electrolytic nickel and electrolytic cobalt refined from granular cobalt. These metals were melted in an induction furnace and cast in iron moulds, about 10 mm in diameter. Seven alloys were prepared, containing respectively 10, 20, 25·08, 33·43, 50·13, 66·7, and 75% cobalt. After hot-forging, the alloys were machined into rods of about 4 mm diameter and 100 mm length. For measurements in the annealed state, the specimens were heated in a vacuum for 3 hr at 1000°C in an electric furnace and then cooled to room temperature at a rate of 200°C per hour.

The measuring equipment used is shown schematically in Fig. 1. The specimen is mounted in a search-coil wound with non-magnetic nichrome wire, cemented on the upper surface of a silica holder of semicircular cross-section, as shown in the inset. The magnetostrictive elongation of the specimen is transmitted to a roller, fitted with a mirror, through a silica tube, one end of which is tightly fixed to a brass block. The assembly is mounted in a brass case, on one side of which is fitted a transparent silica tube, covering the specimen and the holder and making it possible to carry out measurements in a vacuum. The specimen is heated electrically and surrounded by a magnetizing coil.

Magnetization was measured by the conventional ballistic galvanometer method, and magnetostriction by means of a scale and telescope used in conjunction with the apparatus. The specimen was first thermally demagnetized by heating for 30 min at 1000°C in the furnace and then cooled down to the measuring temperature at a rate of 200°C per hour. As soon as this measuring temperature was attained, the external field was applied, and the magnetostriction and magnetization were observed. Time changes in both magnetostriction and magnetization were first measured every few seconds, then every few minutes, and finally every few hours, by removing the external field in the case of magnetostriction and reversing its direction in the case of magnetization.

The results of this investigation establish that the magnetostriction and magnetization of nickel-cobalt alloys show remarkable relaxation phenomena at temperatures above 300°C, the effect being closely associated with the time change in magnetostriction at high temperatures. Furthermore, as the time-change curve is similar in form to a micro-creep curve of some metals, it is considered that the effect may be caused by some sort of micro-creep phenomenon, i.e., by displacement of impurities or lattice defects caused by magnetostriction at high temperatures.

The effect of isothermal magnetic annealing on magnetostriction and magnetization can scarcely be observed at low temperatures, but begins to be noticeable at about 300°C, being particularly apparent at about 350°C. With a further rise in temperature, the effect shows a decrease, eventually vanishing at the magnetic transformation temperature. In the temperature range in which isothermal magnetic annealing is effective, both magnetostriction and magnetization show relaxation phenomena. The amount of the time change in magnetostriction increases with an increase in the strength of the field applied during annealing and the duration of annealing in the field. The time required for magnetostriction and magnetization to reach their final values is reduced when the isothermal annealing temperature is increased. The time change in magnetostriction at high temperatures is delayed when the duration of heating at the measuring temperature without an external field is increased.

Finally, it should be mentioned that, as isothermal magnetic annealing continues, the negative magnetostriction in the normal annealed state becomes smaller, and even becomes positive, showing that nickel-cobalt alloys have a considerable anisotropy in magnetostriction at high temperatures.

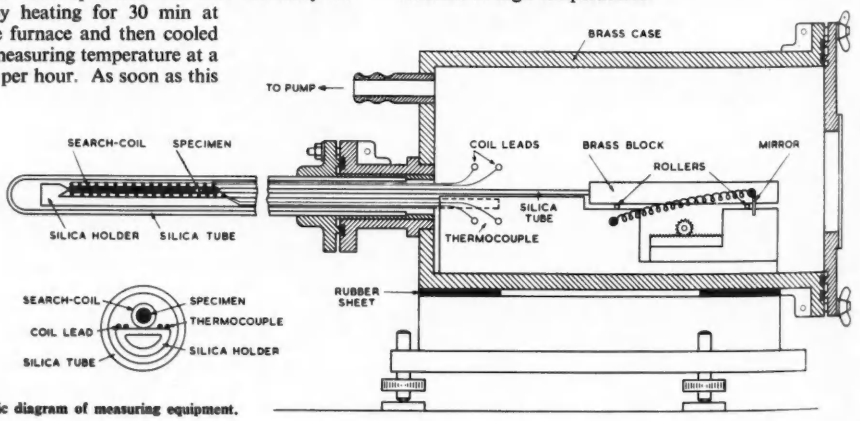

Fig. 1. Schematic diagram of measuring equipment.

Reactor for Direct Conversion of Nuclear Energy into Electric Power

By S. A. COLGATE and R. L. AAMODT. (From *Nucleonics*, Vol. 15, No. 8, August 1957, pp. 50-55, 1 illustration.)

In this paper, a design of plasma reactor is proposed for converting fission energy directly into electricity by causing ionized U^{235} gas to interact with a magnetic field. Although the scheme proposed is purely conceptual, design calculations indicate that it may prove both technically and economically feasible.

IN present procedures for converting nuclear energy into electric power, conventional arrangements of intermediate coolant circuits, heat exchangers, and turbogenerators are cumbersome, inefficient, and expensive to maintain. Although many investigations have been made into the possibility of converting nuclear energy directly into electricity, no economically practicable scheme has as yet been advanced. In an effort to alleviate this situation, the authors of this paper offer for further consideration the conceptual design of a reactor which converts the energy produced in the fissionable material directly into electrical energy by causing ionized U^{235} gas to interact with a magnetic field. Rough design calculations show that the scheme may prove to be technically and possibly even economically feasible.

BASIC CONCEPT OF FISSION-PLASMA REACTOR

The proposed reactor is cylindrical in shape and contains the fissionable material in gaseous form. The temperature of the gas is high enough to ensure that part of it is ionized, the direct conversion being accomplished by making the ionized, and therefore electrically conductive, gas do work against a magnetic field. The work done against the field appears as electrical energy in an external circuit. The dynamic motion of the plasma or hot gas is so arranged that, after each interaction with the magnetic field, the plasma configuration is reshaped by solid walls, so that magneto-hydrodynamic instabilities cannot grow from cycle to cycle.

Basically, then, the reactor is a long cylinder of refractory material surrounded at each end by a neutron reflector and moderator. The cylinder is filled with a fissionable gas, e.g., U^{235} or Pu^{239}, and the amount of gas is adjusted so that, when it is uniformly distributed, the system is just below criticality. Thus, any disturbance causing more fissionable material to be at one end of the cylinder than the other will result in multiplication and heating of the fissionable gas in the critical end. If the neutron-multiplication time is small, compared with the time required for sound to travel the width of the critical region, then the temperature of the fissionable gas can increase by a number of times before a large fraction of the mass of the gas has been expelled from the critical ends. Under these conditions, a shock phenomenon will appear. The shock wave will travel from the heated or critical end down to the low-density opposite end. On the way it will pass through a magnetic field generated by a current-carrying coil surrounding the middle of the cylinder, as in Fig. 1.

Fig. 1 also shows the three regions making up a typical shock wave. The shock disturbance, or shock front, is formed by very rapid heating of a volume of gas, here called the " driving gas ". The shock front travels away from its point of origin at some velocity greater than the speed of sound. The driving gas continues to expand and travels behind at a velocity somewhat slower than that of the shock front. There is then a disc-shaped region between the shock front and the driving gas which grows in length and travels at a velocity intermediate between the other two. This region contains the " shocked gas "—the gas that has been swept up by the shock since it started out. Characteristically, the shocked gas is hotter than the driving gas. In the reactor this region of superheated gas will be sufficiently ionized to act like a conductor.

It is this disc-shaped conductor moving behind the shock that transfers energy to the magnetic field. When the disc of conducting gas enters the magnetic field, it experiences a retarding pressure equal to $H^2/8\pi$ dynes/cm^2, where H is the magnetic field strength. If the shock pressure is greater than the magnetic field pressure, the conducting disc will be forced into the coil, despite the magnetic field. When the disc moves past the centre plane of the coil it suffers a reverse pressure from the magnetic field, tending to expel it from the field.

During its approach, since the force on the disc is opposite to its motion, the disc does work on the magnetic field, i.e., some of its kinetic energy is transferred to the magnetic field. The magnetic field passes this energy to a resonant condenser bank attached to the coil (Fig. 1). As the energy is fed into the resonant circuit,

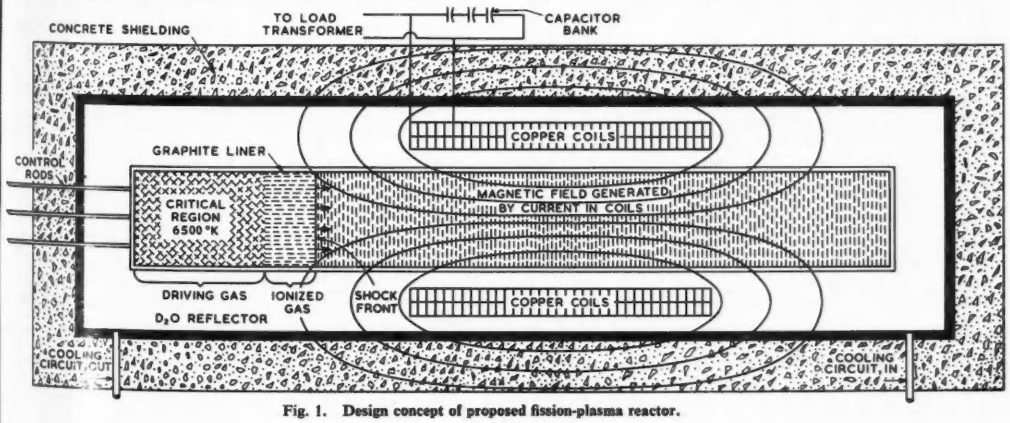

Fig. 1. Design concept of proposed fission-plasma reactor.

some of it can be drained off to do useful work, and some of it is returned to the disc through work done on the disc by the magnetic field as the disc leaves. The work done on the disc when leaving is always less than that done by it when entering. As a result, the disc suffers a net loss in kinetic energy because of its trip through the coil. The energy lost by the disc appears (except for some unavoidable losses) as useful work in the external circuit.

The shock and gas flow continue beyond the coil into the opposite (so far non-critical) end of the cylinder. The flow will continue until there is considerable compression in this end. At some point in the compression, sufficient fissionable material will be accumulated to become critical, the plasma will be rapidly heated, and a reverse shock will take place. The cycle therefore consists of a series of oscillating shock waves produced by the alternate criticality of either end of a cylindrical system. A magnetic coil oscillating with a condenser removes some of the kinetic energy of the gas flow behind the shock. The coupling between the magnetic field and the gas comes from the electrical conductivity of the extremely hot ionized gas.

In the design shown in Fig. 1, the gas is surrounded by a cylindrical graphite container, 0·5 in. thick, the inside wall surface of which is at a temperature of 3500°K. The graphite itself is surrounded by a D_2O blanket which provides neutron moderation and reflection, and removes heat from the graphite, which acts as a thermal shield to keep the temperature of the D_2O below boiling point. The electrical power output of the proposed design is about 500 MW, and the cylindrical reaction chamber is about 25 ft in diameter and 150 ft in length, these being the minimum feasible dimensions for this reactor.

Advantages and Disadvantages

Compared with a conventional reactor, a plasma reactor would have the following advantages:—

(1) Since it is a low-pressure system and the supporting structure is at low temperature, the structural hazards are reduced.

(2) The fissionable material is the working gas, so that no heat exchangers need handle the radioactive material.

(3) No prime turbine is needed, although the same quantity of rotating electrical equipment will be used.

(4) Because the fissionable material is at extremely low density, the prompt-fission multiplication rate is low enough to allow mechanical control of power excursions. In addition, it can be shown that the criticality achieved by shock compression decreases, once the radiation rate increases above the operating condition, so that the reactivity has a negative temperature coefficient above the normal operating temperature.

(5) There is the distinct possibility that the thermodynamic efficiency can be raised to 50%. This would be considerably higher than the efficiency of any conventional system.

The disadvantages are as follows:—

(1) If uranium metal is used as the gas, the wall temperature of the reactor must be very high, i.e., about 3500°K. The use of carbon in this condition has not yet been sufficiently studied to determine feasibility, but other programmes may develop the technology required. The discovery of a gaseous uranium compound which is stable at high temperatures would help this problem.

(2) The minimum theoretical size is quite large. This makes research effort difficult, but the size is not beyond that of modern large power plants.

Design-Parameter Estimates

To determine the engineering feasibility of such a device, estimates are needed for such design parameters as the operating temperatures of the gas and the container walls, the physical dimensions of the reactor cylinder, the density of the gas, the total power output, the strength of the magnetic field, the frequency of the critical oscillations, and the overall power-plant efficiency. The physics aspect of the situation is obviously quite complicated and involves these quantities in relationships which are not easy to describe mathematically. In fact, a careful attempt to determine the physical variables of the system would be a very difficult task and would require supporting experimental investigation. It is possible, however, to start with a few reasonable assumptions and to use "order-of-magnitude" arguments to obtain rough estimates of the design parameters. This kind of approach has produced the following results:—

Ratio of cylinder length to diameter	6:1
Minimum theoretical diameter of cylinder	25 ft
Length of cylinder	150 ft
Maximun operating temperature of gas	6500°K
Maximum operating temperature of graphite wall	3500°K
Gas density*	5×10^{17} atoms/cm³
Gas pressure	~ 1 atm
Total electrical power generated	480 MW
Magnetic field strength	3170 gauss
Velocity of expanding gas	$1{\cdot}6 \times 10^5$ cm/sec
Oscillation frequency	~ 20 cps
Thermodynamic efficiency	30%
Overall power-plant efficiency	20%

In deriving the above estimates, the following assumptions mave been made:—

(1) The gas is uranium metal (B.P. = 3900°K).

(2) The gas is surrounded by a cylindrical graphite container, which is itself surrounded by a D_2O blanket.

(3) The maximum heat flux through the graphite is 1 kW/cm², and the inside wall temperature is 3500°K.

(4) The conversion from mechanical to electrical energy is 70% efficient and does not include thermodynamic efficiency.

Although some of the values given above are extreme, none appears to be completely beyond reality. All have been derived from physical arguments† intended to give order-of-magnitude design estimates, rather than precise values, and certainly it would appear that the construction of a fission-plasma reactor is feasible enough to warrant a more thorough investigation. In this connection, the design uncertainty most in need of experimental investigation is the effective electrical conductivity of the plasma, which has been estimated on the assumption of an electron velocity distribution very close to thermal. High current density, large inelastic-collision cross-section, and large nuclear ionization are all effects tending to cause an electron velocity distribution different from thermal. Fortunately, however, these effects are in the direction of higher conductivity, i.e., towards a smaller minimum size of reactor.

Admittedly, experimental investigations must be made on equipment which is close to the actual size, but this is not as great a problem as might be imagined. Thus, a shock-tube, only 1 metre in diameter and 6 metres in length, operating at a maximum pressure of 1 atm with a magnetic field of 5000 gauss at the midpoint, would give complete answers not only to electrical conductivity, but also to electrical cycle efficiency, radiation cooling, and thermal conductivity.

* The density of air at standard temperature and pressure is 5×10^{19} atoms /cm³.

† In the original article, detailed estimates of all parameters are included. *Editor, E.D.*

Method of Recording Vibrations in Turbogenerator Foundations and Power-House Structures

By A. MAJOR. (From *Acta Technica Academiae Scientarum Hungaricae*, Vol. 18, No. 3-4, pp. 295-316, 10 illustrations.)

THOUGH of outstanding importance, measurements of the vibrations set up by the acceleration and deceleration of unloaded turbogenerators have generally not been extended to both the machine foundations and to the structural elements of the surrounding buildings. It is known that, with regard to vertical natural vibrations, the foundations of high-speed turbogenerators, apart from structures of exceptionally low natural frequency (e.g., steel structures or structures with prestressed concrete frames), are as a rule overtuned, i.e., their natural frequency exceeds the operating speed ; on the other hand, the horizontal natural frequency of machine foundations is usually lower than the operating speed, so that, insofar as horizontal vibrations are concerned, even overtuned foundations can usually be said to be undertuned.

Ever since it became customary to employ prefabricated or partly prefabricated reinforced-concrete structures for the building of power-houses, the natural frequencies of their structural elements have tended to be lower than the operating speed, so that they are usually undertuned. The critical speed of the main shaft is, of course, always run through as quickly as possible, so that, in practice, it is only for a short interval that disturbing frequencies are set up during acceleration. The situation is, however, somewhat different when the machine is being brought to a standstill, an operation which usually takes from 40 to 60 min, during which time the rotor may run for 1 to 2 min in the vicinity ($\pm$ 5%) of any range of frequency. This period is sufficiently long for the natural frequencies of the undertuned elements to coincide with the actual rotational speed and to set up resonant conditions for a few minutes. It is therefore possible that all structural elements will start to vibrate with considerably increased amplitudes, either as a result of vibrations set up in them by the speed of the rotor, or because of disturbing forces which become intensified when the rotor runs through its own critical speed.

As described in this paper, a suitable method has been devised for measuring and analysing the vibrations set up in the foundations of a turbogenerator and in the partly prefabricated adjacent structural elements of the building of a power-plant. These measurements were made during the test-run of a turbogenerator and extend to transitory resonance, the object being to obtain simultaneous records of vibrations set up at several points of the machine foundations and the surrounding buildings by the turbogenerator, rotating at various speeds when accelerated and decelerated during the 40 to 50 min of its first test-run.

To effect these measurements with normal methods would have required the use of a large amount of recording equipment and personnel, while synchronization of the measurements would have been extremely difficult to carry out simply. As a result, a new method of synchronized vibration measurements was devised, basically comprising the use as receivers of geophones of the type generally employed in geophysical surveys and a number of galvanometer oscillographs placed side by side and registering on a common strip of film.

The various parts of the equipment were mounted in a specially adapted motor lorry. Cables were used to connect the central installation in the lorry with the various points to be measured, twenty-six receivers and cables being employed to register synchronous vibrations. A telephone in the lorry, capable of being connected to any of the cables, made it possible to establish communication between the operator in the lorry and observers at any measuring point, a telephone, provided with loudspeaker and microphone, serving to identify the individual measuring points.

The galvanometers and time signals transmitted their records to a common sensitized paper strip moving at a speed of 35 cm/min, i.e., sufficient to ensure satisfactory recording of movements of only 0·01 sec duration. Photographing processing facilities were provided in the lorry. To ensure satisfactory transfer of vibrations, the casings of the geophones used as receivers were attached to the elements to be measured with plaster-of-paris.

A diagrammatic cross-section of the power-house used in these experiments is shown in Fig. 1. With the exception of some of the monolithic ceilings, the structure is composed of prefabricated elements. The members of the five ranges of pillars are rigidly built into the foundation, and the roof girder *G* of the turbine-house (an end-supported beam) rests on pillars *D* and *E*, while the roof girder *F* of the boiler-house (also an end-supported beam) rests on pillars *B* and *I*. The foundations of the turbogenerators are isolated from the surrounding buildings.

Of the geophones used, nineteen served for purposes of measurement proper, one was used to indicate possible extraordinary disturbances, and another to register rota-

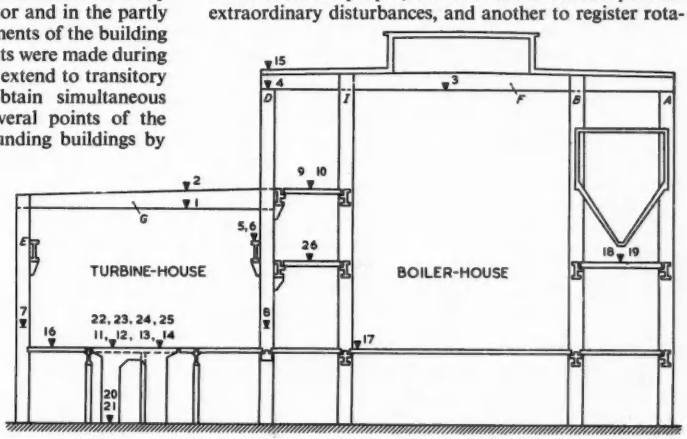

Fig. 1. Diagrammatic cross-section of turbine-house and boiler-house.

tional speed. Thus, as can be seen from Fig. 1, geophone No. 1 was located on the roof girder *G* of the turbine-house, No. 2 on the floor of the roofing structure of the turbine-house, No. 3 on the middle part of the roof girder *F* of the boiler-house, No. 4 on its projecting end, Nos. 5 and 6 on the craneway beams, No. 7 on pillar *E*, No. 8 on pillar *D*, Nos. 9 and 10 on the upper ceiling, Nos. 11 to 14 on the four corners of the turbine foundation (above the pillars), No. 15 on the roof of the boiler-house, No. 16 on the monolithic structure next to the turbine foundations, No. 17 in the boiler-house, flush with No. 16, and Nos. 18 and 19 on the ceiling below the bunkers. Subsequent individual, i.e., unsynchronized, control measurements on the loaded turbine were made at points 20 to 26, i.e., Nos. 20 and 21 on the base of the foundation, Nos. 22 to 25 on the turbine foundations, and No. 26 on an intermediate floor at the side of the turbine-house. These individual measurements were made because of certain conspicuous vibration amplitudes recorded in the original measurements.

After recording "initial disturbances", the turbo-generator was started up. During the first run, it was desired to increase the speed in steps of 100 rpm, to hold the speed for a short time, and to make the necessary measurements before proceeding to the next higher step. Although it was found more or less possible to carry out this scheme, the actual increases in speed were slightly higher or lower than 100 rpm, owing to the relatively low sensitivity of the revolution counter and to irregularities in steam pressure. However, this was not a drawback, as the actual speed of the rotor could always be determined from the final characteristic curves of the vibrations and from the revolution counter connected with one of the galvanometers. Stepping up the speed in this way was found practicable only up to about 1500 rpm, as the critical speed of the rotor was 2100 rpm and, in order to pass through this speed as quickly as possible, it was necessary to accelerate more rapidly until reaching the operating speed of 3000 rpm, when new measurements were made. Although this, of course, meant that a certain speed range had to be missed out, it was of no great importance, as the natural frequencies of the structural parts under examination were, with the exception of the craneway beam, which had a natural frequency corresponding to 2100 rpm, generally in the region below 1500 rpm.

Results of Measurements

The curves of vibrations registered by the geophone at point No. 3 in the middle part of the boiler-house roof showed that the amplitudes were quite negligible, establishing that the effect of vibration at this point was virtually imperceptible. In the case of point No. 2 on the roof, a double amplitude of 10μ (i.e., a swing of 5μ) at the operating speed of 3000 rpm was noted. Preliminary measurements had shown the natural frequency of the elements at point No. 3 to be 15 cps, which corresponds to a speed of about 900 rpm. Consequently, these elements are undertuned but, owing to the great distance involved, no vibrations with amplitudes corresponding to the speed of the generator can reach the roof girder.

In the case of the vibration curves registered at points 5 and 6 on the craneway beams, one peak was visible at a speed of 700 rpm, another at 1100 rpm, and a third at 1400 rpm, with double amplitudes of about 10μ at the operating speed of 3000 rpm for both points. According to preliminary examination, the natural frequency corresponded to 2100 rpm and, as this is within the range of critical speed, no measurements could be made.

The curves of vibrations at point No. 7 on the outside pillar of the turbine-house showed peaks around 700 and 1000 rpm, with a negligible amplitude at the operating speed. At point No. 16 on the floor beam, a sudden increase in amplitude at a speed of 800 rpm was noted. The amplitude at the operating speed was found to remain below 10μ, as in previous cases.

Curves of vibration registered in two corners of the turbine foundation at points 11 and 12 showed conspicuous peaks around 700 and 1100 rpm, and preliminary measurements established this element to be strongly overtuned at the operating speed. The fact that the other curves also show suddenly increased amplitudes in the region of 700 and 1100 rpm supports the assumption of a transitory resonance at one of these points. According to preliminary measurements, the natural frequency of the frame of the turbogenerator corresponded to 4000 rpm, so that no resonance was set up at the considerably lower operating speed of 3000 rpm. However, subsequent calculations, in which due regard was given to the joint deformation of the frame and bed, gave 700 rpm as the speed corresponding to the natural frequency of these combined elements, and it was this combined, true natural frequency to which were due the resonant conditions set up at the first high amplitude peak. Similar amplitude peaks at a speed of 600 to 700 rpm at several points in the surrounding structure must have been due to a simple transfer of the resonance via the soil.

This method of recording and analysing vibrations has shown that it is possible to determine the extent to which vibrations set up by turbogenerators are transmitted to surrounding structures. In the present instance, it is clear that vibrations do not spread beyond the turbine-house and that their effect is practically imperceptible in the boiler-house. Furthermore, no structural element was found to be in resonance at the operating speed, and the vibration amplitudes observed were more or less in agreement with those established by other authors. It was also found that, in agreement with the observations of other investigators, frequencies corresponding to a speed of 1100 to 1200 rpm are twice as high as the disturbing frequency, and above this speed are equal to it.

When the turbine rotor reaches a speed which coincides with that corresponding to the natural frequency, resonance is set up in undertuned structural elements. Resonance of this kind cannot be observed in cases where natural frequency and that corresponding to critical speed are close together but, when dealing with undertuned elements, due regard must be given to the effect which resonance set up during acceleration and deceleration exercises on the forces involved in computations. Certainly, there can be no doubt that such resonance must not be disregarded, even though the extent of the actual transitory amplitudes noted may not appear to be at all dangerous.

It is concluded that vibrations should be investigated not only in respect of the machine foundations but also in the surrounding structures, especially if prefabricated or partly prefabricated elements are employed in their construction. It is also considered that this investigation shows that a skilful use of correctly joined prefabricated structures is by no means incompatible with fully satisfying all requirements raised by considerations regarding vibration, and that this method can be applied successfully to clearing up vibration conditions in turbine foundations and surrounding buildings.

British Industrial Developments

Automatic Production Lines for Tapered Roller Bearings

In view of the wide publicity given to the automatic production lines for the manufacture of tapered roller bearings by Timken at their Bucyrus Plant, Ohio, it is gratifying to note that British Timken Ltd. have installed similar facilities at their new Duston Plant.

Comprising a floor area of 33,000 sq ft, the new plant is divided into three main departments, i.e., an automatic machine shop for producing machined components from tube, a hardening shop for the heat treatment of machined pieces, and a grinding shop, which includes cup, cone, and roller grinding, as well as assembly, greasing, and packing sections. The building is equipped with its own boiler-house, water storage, compressor-house, and electrical substation. Air conditioning, supplying extraction filtration and hot and cold recirculation, is also provided.

Tooling and change parts exist at present for the larger cup line in four different sizes, for the smaller cup line in five sizes, for the larger cones in three sizes, and for the small cones in four sizes. Components produced on the four lines simultaneously are merged together at the packing section to form two complete bearing sizes. Inspection throughout is operated on a statistical quality-control basis, checks being taken at the machine at regular intervals. Intermediate spot checks are also made, and, in addition, there is a 100% inspection at the completion of manufacture on certain visual and dimensional standards.

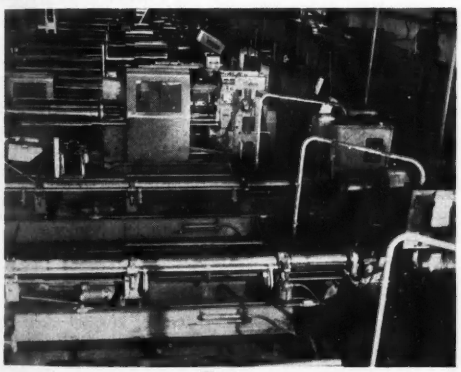

Fig. 1.

The automatic machine shop, a general view of which is shown in Fig. 1, is divided into four lines. Of these, line 1 consists of three carbide-tooled single-spindle Timken automatics, producing cups ranging from 2¼ to 3 in. o.d., a separate final chamfering machine, and a Schmidt peripheral marking machine. All three single-spindle Timken automatics discharge into bulk storage, from which the components are mechanically sorted for chamfering and marking.

Line 2 is equipped with two carbide-tooled five-spindle Wickman automatics, producing cups from 1⅛ to 2 in. o.d. Final chamfering here is incorporated in the Wickman tooling, and only a single-deck spiral brush feeder is required to supply the cups to a separate Schmidt marker.

At the moment, line 3 is being changed over to carbide-tooled 2¼-in. six-spindle Wickman machines, which are capable of an included final chamfering operation, as in the case of the small cups. Cone marking on the broad face is effected with a 25-ton crank press, incorporating a fixture specially designed to avoid rib distortion during pressing. A single-deck brush feeder provides buffer storage between machining and marking.

Line 4 is arranged for small cones and consists of three 1⅛-in. four-spindle Acme Gridley machines, a separate vertical chamfering machine, and similar marking to line 3. A small bulk-storage hopper and sorting mechanism are used to supply cones for chamfering and marking, as for the larger cups.

Work produced on each line is separately elevated into large bulk-storage hoppers, situated between the automatic machine and heat-treatment shops. These are large enough to facilitate complete changes of tooling without disrupting production in the following departments.

Swarf ejected from multi-spindle machines is conveyed in ducts by pneumatically operated forks, whilst the single-spindle Timken automatics are cleared by high-pressure coolant jets in a separate duct. Both systems enter the swarf house, where the swarf is crushed and distributed in a container for collection.

At present, tubes are loaded into the automatic machines by hand, but sufficient floor space has been allowed for loading-racks in the future. To reduce change-over times and to eliminate adjustments at the machine, the tool sets for the various operations are preset in blocks and held in readiness for replacement or change of symbol. A separate enclosure exists for grinding and resetting.

In the hardening shop, the heat-treatment processes involved are (1) carburizing for 7½ to 10 hr at 920°C, giving a case depth of 0·035 to 0·055 in., depending on the size and section of the component, (2) quenching in oil, (3) hardening by reheating to 780°C, and then quenching again in oil, and (4) tempering at 165°C for 2 hr and allowing to cool in air, two entirely different installations being used for this purpose, as some of the larger cups of thin section require controlled jig-quenching during the hardening process, to avoid distortion and to maintain minimum grinding stocks.

Machined cones are vibrated from bulk storage and elevated at controlled rates into a continuous rotary spiral carburizing furnace. After quenching at the discharge end, they are washed in a spiral washing machine, before entering the hardening furnace, and washed again between the hardening quench and the tempering furnace.

All three furnaces are gas-fired and are fitted with automatic controls and safety devices. Separate sulphur extraction and "RX" gas-generating plants treat the town gas before its supply as the carburizing medium. Propane is finally added to the treated town gas before entry to the carburizing furnace.

A separate set of four bulk-storage hoppers for cups exists in the second heat-treatment section, which consists of two electrically heated pit-type carburizing furnaces, a quench receptacle capable of circulating oil at 2400 gpm, and a circular trichlorethylene vapour degreaser, all installed in a circle of 7-ft radius. A general view of the cone section of the heat-treatment department is shown in Fig. 2.

Movements of work between these operations are not fully automatic but are effected by a central crane used for lifting stacks of three nickel-chrome work-containers. Components are vibrated into the containers from bulk storage, carburized, quenched, and emptied into a jig-hardening feed hopper after the degreasing operation.

Cup hardening consists of reheating to 780°C, and jig-quenching for a period varying between 7 and 10 sec,

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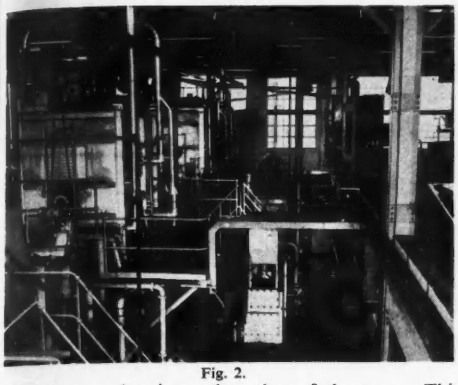


Fig. 2.

depending on the size and section of the cups. This equipment is completely automatic, consisting of an eight-lane electric furnace, discharging at preset intervals into two hydraulic jig-quenching machines. A hopper-fed one-way turn-over unit and eight-way distributor supply the furnace pusher mechanism. Components entering the pusher unit are timed to move relative to the quenching period required, and in two lanes at a time. A slow-moving conveyor receiving jig-quenched components provides complete cooling in an oil bath before elevating them for the subsequent tempering operation. The tempering furnace in this section is electrically heated, and is equipped with a variable-speed belt and a device for the uniform distribution of components. Between the tempering operation and shot-blasting it is necessary to re-sort the components and store limited quantities. Specially designed continuous shot-blasting machines will soon be used for both cups and cones. Four machines in the cup heat-treatment section will continuously feed the grinding department. At present, one machine only is installed on a development basis.

Fig. 3.

A supply of quenching oil to both heat-treatment sections is obtained from the service block, where two 5000-gal storage tanks and multiple pumping sets are housed. Two thermostatically controlled Heenan and Froude coolers maintain the correct oil temperature.

After heat treatment, the components proceed to the grinding shop, where they are again separated into four distinct lines for grinding operations, individual grinding lines being installed for the larger and smaller cups and for their corresponding cones. Both cups and cones are held in bulk-storage hoppers similar to those between the automatic machine and hardening shops, and automatically supplied to the grinding lines, as required. A general view of the cup-grinding lines is shown in Fig. 3, and of the cone-grinding lines in Fig. 4.

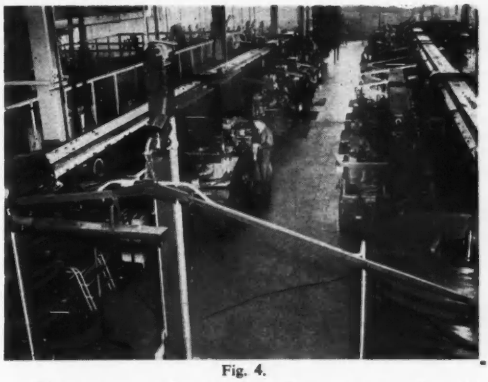


Fig. 4.

The sequence of operations for cups comprises (1) face grinding, (2) o.d. grinding, (3) bore grinding, (4) bore honing, (5) washing by high-pressure jets of distillate directed from above and below a twin-lane mesh belt, (6) 100% visual inspection, during which the cups are fed at a controlled speed along specially designed rails, and viewed for finish, chamfer and marking defects, surface cracks, etc., (7) automatic air gauging (to be installed later this year as a final acceptance inspection and capable of automatic separation of any components not within the prescribed specification), and (8) greasing by complete immersion on a moving belt.

Mechanical handling and storage devices between the various grinding operations consist of spiral brush feeders with capacities arranged to suit production and tooling change requirements, adjustable vertical chain elevators, one-way turn-over units, cup alternators which can turn components back to back for o.d. grinding, and circulating conveyors. The latter are sectional conveyors of sufficient length to cover groups of different machines with similar total output capacities. One such conveyor is used on each cup line situated behind the bore grinders and honing machines, its purpose being to circulate components continuously to the machine-feed chutes. When each chute is full, surplus components continue to circulate on the same section of conveyor waiting to fill a vacant position in the machine-feed chute. Finished ground components are elevated to the next conveyor section, where a similar process takes place before the honing operation. A system of limit-switches controls the work flow onto the conveyor, allowing sufficient storage during circulation to cover routine stoppages such as grinding-wheel changes.

The two cone sizes are simultaneously processed with the cups. The operations involved, identical for both lines, comprise (1) face grinding, (2) race grinding, (3)

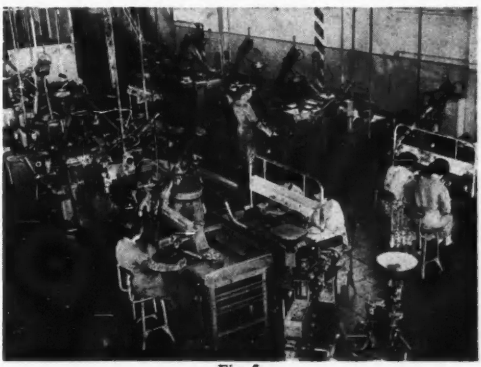
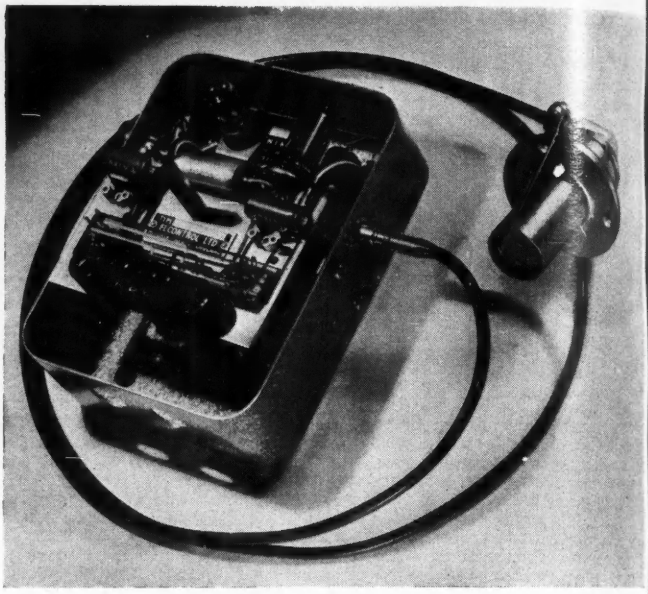


Fig. 5.

PUSH BUTTON BURNER CONTROL



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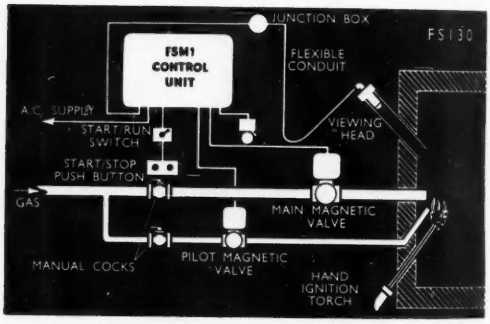

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bore grinding, (4) rib grinding, (5) race tape honing, (6) distillate cleaning by means of automatic jet washing machines, (7) 100% visual inspection, as in the case of cups, (8) automatic air gauging (also to be installed later), (9) semi-automatic assembly of cones, rollers, and cages, the latter being supplied as a finished product from the adjacent main factory, (10) final washing, as in the case of cups, and (11) greasing by total immersion.

At present, two different types of roller are required to match the factory output. In the roller section, these are produced on two continuous lines, installed with almost identical equipment. A number of predetermined grades or size groups (each group differing by less than 0·00025 in., or half-grades of 0·000125 in. in body diameter) can be produced, as necessary.

Rollers enter the grinding lines after the earlier operations have been carried out in the main factory. These operations of heading, barrelling, and hardening are made on a batch basis by conventional equipment. Operations in the roller section comprise (1) rough body grinding, (2) a second body pass, (3) spherical roll end grinding, (4) a finish body pass, (5) automatic washing and drying, (6) visual inspection, and (7) automatic grading on machines capable of segregating rollers into size groups. A view of the visual inspection and grading section of the roller production lines is given in Fig. 5.

Packing of the finished product after final greasing involves the placing of either complete bearings or of separate cups and assembled cones, depending on customers' requirements, into cylindrical cartons. One machine exists at present in the final stages of development, capable of performing this operation at a rate of 42 bearings per minute. Four such machines will be required finally, but at the moment the whole operation is done by hand, including capping and stamping the cartons.

All bore-grinding, rib-grinding, and honing machines are hydraulically operated from a central pumping system employed to circulate oil at 150 psi. The system includes a by-pass centrifuge for continuous purification, and stand-by pumps.

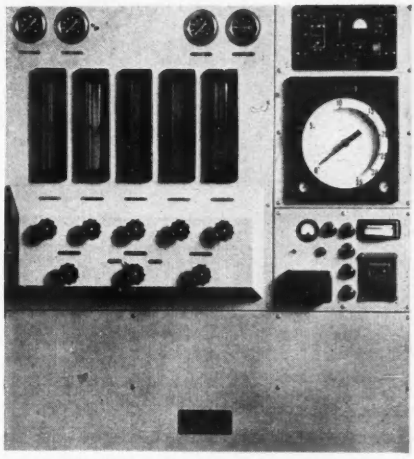
High-frequency wheel-heads are used on all bore grinders, the electrical supply for these being generated by four alternator sets, with two additional sets held in reserve. Since the bore sizes of the components produced vary for each line, different spindle speeds are required. Thus, the four alternators are driven to produce different frequencies. Alternators can be reconnected to any one line and its frequency readjusted at a few minutes notice in case of breakdown.

Service mains, i.e., grinding-coolant supply and return, compressed air, hydraulic supply and return, normal electrical supply, and high-frequency supply, are encased in the circulating conveyors. One main service trench provides the link between all four lines, and continues into the service block, where the grinding coolant is pumped and cleaned magnetically.

Generator for Furnace and Blanketing Atmospheres

A new and improved model of their " Nitroneal " generator for producing furnace and blanketing atmospheres, consisting of nitrogen with a controllable hydrogen content, using ammonia as fuel, is announced by the Baker Platinum Division of Engelhard Industries Limited, of London, W.C.1. The new model, known as the GNL Nitroneal Generator, is made in two sizes, producing respectively 500 and 1500 cubic feet per hour of gas, and, unlike the earlier models, which required an ammonia vapour supply, has a built-in vaporizer and is fed with liquid ammonia directly from the cylinders. The refrigerating properties of the ammonia are used to cool the gas down to a dew-point of 40°F.

The gas is produced by cracking the ammonia over a precious-metal catalyst into nitrogen and hydrogen, and the same catalyst is used to burn the bulk of the hydrogen



with atmospheric oxygen to produce a gas containing from 0·5 to 25% hydrogen. The principal advantages obtained by using the special Baker catalyst in this way are that the reaction is exothermic, and no external heat source is required ; in addition, by utilizing nitrogen from the atmosphere, as well as from the ammonia, the gas is produced very economically. In the new model, a second-stage catalyst chamber is used when the hydrogen concentration required is less than 15%, and this further change in design considerably prolongs the life of the catalyst. It also ensures that the oxygen content of the gas is less than one part per million.

The hydrogen content of the gas is controlled automatically within 0·25% of the desired concentration, and the generator merely requires the attention of an operator for starting, which takes about 20 min. There are no pumps or other moving parts, so that servicing and maintenance are reduced to a minimum.

High-Temperature Nickel-Chromium-Base Alloys

A range of high-temperature nickel-chromium-base alloys, designated " Nimocast ", for use in the cast form has been introduced by Henry Wiggin & Co. Ltd., of Birmingham. Six alloys are now available in the series, five of which were developed in the laboratories of The Mond Nickel Co. Ltd. These alloys are complementary to the " Nimonic " series of wrought heat-resisting alloys, and some of them were previously included in the " Nimonic " series.

Nimocast 75 (formerly Nimonic C.75) may be used under conditions involving low stresses, but requiring good resistance to oxidation. It does not respond significantly to heat treatment and is normally used in the as-cast condition, or after a stress-relieving treatment. On the other hand, Nimocast 80 (formerly Nimonic CC) has considerably higher room-temperature mechanical properties and creep resistance than Nimocast 75. It is normally used in the fully heat-treated condition and is suitable for gas-turbine stator blades and for the precombustion chambers of high-performance diesel engines.

Nimocast 90 (formerly Nimonic CB), the casting version of Nimonic 90, also responds to heat treatment and is mainly used in the age-hardened condition. In general, Nimocast 90 is to be preferred to Nimocast 80 for high-stress, high-temperature applications, because of its better castability and superior strength. At 750°C, Nimocast 90 shows a stress-carrying capacity inferior to that of the corresponding wrought alloy but, at 870°C and above, Nimocast 90 carries at least as high a stress for a given life as Nimonic 90.

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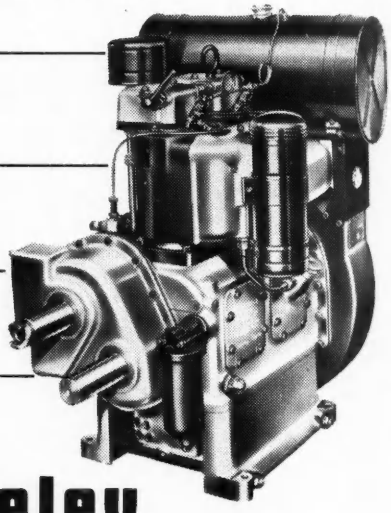

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Nimocast 242 (formerly C.242) was developed by Rolls Royce Ltd. for investment-casting applications involving high resistance to thermal shock. It is used in the as-cast condition at temperatures up to 1050°C for such components as stator blades for gas-turbine engines.

Nimocast 257 (formerly MC.57) has properties which are intermediate between those of Nimocast 75 and Nimocast 90, giving adequate proof stress combined with good ductility at temperatures between 600 and 700°C. This alloy, which is used in the fully heat-treated condition, is of particular interest for centrifugally cast rings for gas turbines.

Nimocast 258 (formerly MC.58) is a recently developed alloy with good stress/rupture properties at temperatures higher than 950°C. This alloy, which has the highest stress/rupture properties in the as-cast condition, is similar in composition to Nimonic 100, the most creep-resitant alloy in the Nimonic series.

High-Speed Ground Tool Bits

It is announced by E. P. Barrus (Concessionaires) Limited, of London, W.3, that high-speed ground tool bits are now being manufactured in the U.K. by Cleveland Twist Drill (Great Britain) Ltd. Made from a special molybdenum steel, these bits are available in two grades, i.e., " Mo-Max " and " Mo-Max Cobalt ". The " Mo-Max " bits have outstanding toughness, hardness, and resistance to tempering, and are intended for average jobs or where great resistance to shock is required. The " Mo-Max Colbat " bits are stated to be the toughest of the cobalt high-speed steels and are eminently suitable for jobs requiring greater red hardness and abrasive wear, so much so that comparative tests with other bits have shown that they provide 43% more production in the machining of a nickel-molybdenum steel at 135 to 150 sfm.

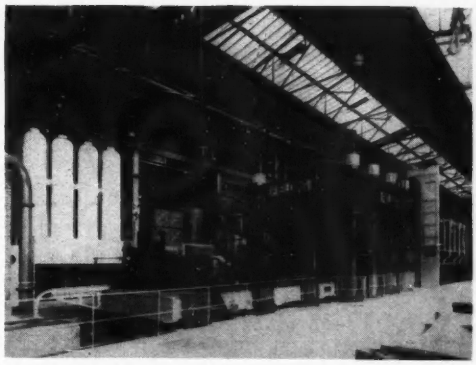
All these bits are of square section, with a 10-deg. bevel on each end, and are available in sizes from $\frac{1}{8}$ in. square × $2\frac{1}{2}$ in. long up to $1\frac{1}{2}$ in. square × 10 in. long, and in a comparable range of metric sizes.

Giant Press for Production of Nuclear Power Reactor Vessels

The pressure vessels now being made for the British Nuclear Power programme each contain well over 1000 tons of steel and are 3 and 4 in. in thickness. In order to make them as economically as possible and to the highest standards, the largest plates available from the steel mills are needed, requiring the use of presses which are outside the normal capacity of those manufactured in the U.K. and necessitating the design and construction of a suitable press to meet requirements.

The result is a giant press which has been made specially by Fielding and Platt Limited for Whessoe Limited, manufacturers of the first eight large nuclear power pressure vessels in Great Britain at Calder Hall and Chapelcross. This design of press handles plates 25 ft in length and 10 ft in width and is one of the largest of its type in Europe. In combination with the furnace and a specially developed plate-handling bogie, it is believed to be the finest integrated plate-pressing facility in the world. Although the press will accept the largest plates manufactured by the British steel industry to-day, a substantial margin of power is still available, so as to meet future developments.

The press is housed in a pit, 31 ft deep, and the weight supported on the foundations is approximately 750 tons. The largest single piece in the press structure is the fabricated top table, which weighs 120 tons, excluding the weight of the dies, whilst the total weight of moving parts is 240 tons. A working space of 12 ft 4 in. × 26 ft 8 in. is available on the moving table, which has an overall length of 27 ft, the overall width of the table over the column guide brackets being 17 ft 3 in., and the overall height of the press above floor level being 21 ft 3 in. The



maximum hydraulic working pressure is 4750 psi, and the total gross power at 4500 psi, allowing for the weight of moving parts, is 4600 tons. The moving table is actuated by eleven high-pressure rams, ten of which are axially bored to form cylinders for ejection rams. A total of seventeen ejector rams is installed; these have a combined power of nearly 150 tons and are operated either singly or in groups through the medium of joy-stick-controlled valves located in the control panel.

The top and bottom tables are located and tied together by eight forged manganese-steel columns. Half collars, housed in recesses on the periphery of the columns, support the top table. The half-collar recesses are arranged to allow the table to be adjusted to the maximum and minimum daylight. Attached to the underside of the top table are the roller paths of the press crane; the crane chassis carries two 10-ton electrically operated blocks. Normally, the crane is housed clear of the press on extension members and is only traversed in when the loading of dies or maintenance is being carried out. The whole crane is designed to facilitate removal for maintenance and inspection.

Two accumulator systems are incorporated in the hydraulic circuit, these being a low-pressure system operating the ejector rams, and a high-pressure system for main operation. Press control is carried out from a central control station, the selection of press working pressure being made by an ultimate power selector switch which automatically brings into operation the required number of rams to meet the specific needs of the pressing taking place. The hydraulic medium for the high-pressure accumulator system is supplied by Fielding horizontal three-throw reciprocating totally enclosed pumps, having a displacement of 35 gpm at a working pressure of 4480 to 4780 psi when operating at a speed of 540 rpm. The pumps are of the fixed-displacement type and incorporate an integral lubricating system, mitre-seat suction and delivery valves, and high-pressure safety valves.

Automatic Method of Producing Perspective Drawings

Hitherto available only in Sweden, the " Autoperspect " apparatus for the automatic production of accurate perspective drawings is now being manufactured in the U.K. by Autoperspective Ltd., of London, S.W.1. The apparatus permits a choice of angle of view and of scale of reproduction, and a selection of one-, two-, or three-point perspectives, using only a plan and elevation drawing of the object. Cut-away views, exploded views, stereoscopic views, topographical details, etc. also come within its scope.

Basically, the apparatus comprises a table (1) on supporting legs, at the rear of which is a main frame supporting a smaller table (2), a vertical table (3)—made of perspex and not visible in the illustration—and a special

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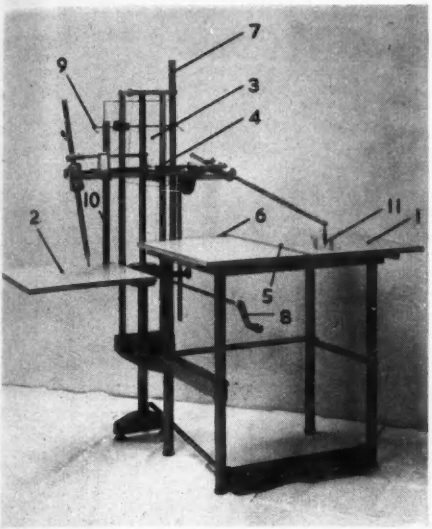


linkage (4) which connects a scriber arm with a pencil bar and transmits a congruent movement between them. In operation, a plan of the object is placed on the table (1) at a predetermined distance from the theoretical viewpoint measured on a scale (5) and at a selected angle which can be measured on a graduated pivot (6). An elevation drawing is then placed on the vertical table (3) and is indexed for height on a scale (7) by operating an elevation control handle (8). When this height has been fixed, an index line (9) is set to an appropriate plane on the elevation drawing. To set the scale of reproduction, the picture table (2) can be adjusted for height, which can be read on a scale (10). A tracer point (11) is then placed on the plan and a foot-control depressed, lowering the pencil bar onto the table (2). Tracing the plan results in the production of a true perspective drawing for the selected plane on the elevation. The handle (8) is then operated to bring another elevation plane under the index line (9), and the operation is repeated. When all planes have been dealt with in this way, a perspective will be completed on the picture table (2).

There is no possibility of error, and the apparatus can be used by those with only a basic knowledge of draughtsmanship. Furthermore, it is stated that, compared with normal methods of producing perspective drawings, the time required is reduced by from three to nine times, depending on the complexity of the finished drawing.

Horizontal Measuring Machine

The " Microptic " horizontal measuring machine, manufactured by Hilger & Watts Ltd., of London, N.W.1, now incorporates an important new feature, the microscope reading system having been replaced by a projector microscope and readings taken from a projection screen. The accuracy and other details of the instrument remain unchanged, but there are several obvious advantages to be derived from having an enlarged image of the field of view projected on a screen, among which may be mentioned the simplicity of taking readings and the reduction of eyestrain.

Special care has been taken in the design of the method of illumination to ensure that heat from the projection lamp in no way affects the accuracy of the instrument. Another point of importance is that, since the direction of travel of the measuring plunger and of the image across the screen are in agreement, no anomalies of reading can result.

Ultrasonic Tapping of Hard and Brittle Materials

It has been announced by Kerry's (Ultrasonics) Ltd., of Romford, Essex, that recent developments in the ultrasonic machining process have made it possible to carry out tapping operations on hard and brittle materials such as tungsten carbide and ceramic cutting tools, all threads being executed in very short machining times.

This development, examples of which were shown by Kerry's for the first time at the recent Engineering, Marine, Welding, and Nuclear Energy Exhibition, now makes possible a number of applications which were previously beyond the capacity of normal processes. Thus, some of the uses immediately envisaged for tapped tungsten carbide and other sintered materials include turning tools with easily fixed and detachable tips, coal-cutting and boring-machinery blades which can be removed without dismantling the machine, screw gauges, and screwing dies for automatics, etc.

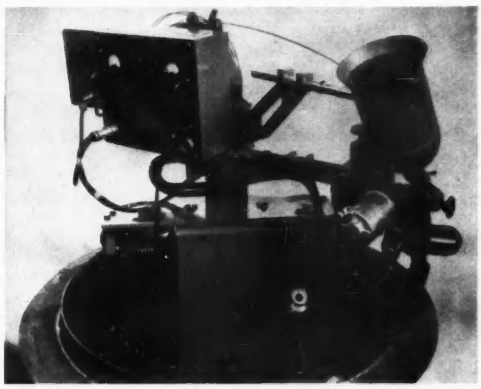
Universal Resistance-Welding Machine Control Units

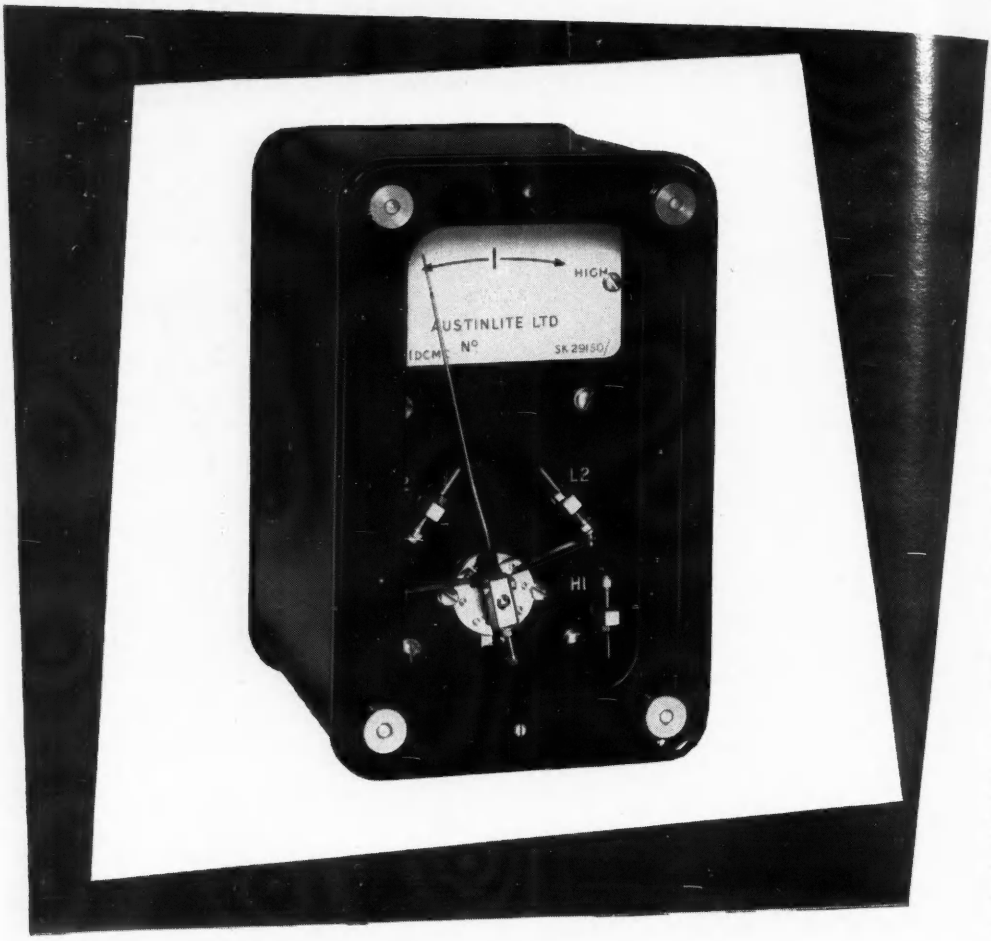
Four universal control units, for use in conjunction with, and housed in, their standard DEK.R/S dekatron control cabinets, have been added to the range of electronic control equipment for resistance-welding plant produced by Sciaky Electric Welding Machines Ltd., of Slough, Bucks. The object is to use only one basic type of machine control circuit for all types of machine, where non-synchronous sequence functions are required, with all the consequent advantages of having interchangeable control circuits for several different types of machine.

Contained within these units are four timers of the same basic circuit, for controlling " squeeze ", " forge delay ", " forge dwell ", and " off " periods, together with a power supply for two Sciaky air valves, two-stage initiation, and a built-in time delay for valve protection. Simplified versions containing fewer stages of control are also available. With the four timer units, numerous combinations of programme are available, including requirements for spot, seam, roll-spot, impulse, and multiple pressure systems.

Boiler-End and Flue Welding Machine

The new boiler-end and flue welding machine introduced by Quasi-Arc Ltd., of Bilston, Staffs., consists basically of a " Unionmelt " D.S. head mounted by means of a special bracket on a self-propelled carriage provided with special traverse wheels and support rollers, so that the tractor will hang from the edge of the boiler shell.





The Austinlite marginal relay

Here is one of the most sensitive instruments of its kind on the market. Its performance is due largely to the powerful heavy duty Alcomax magnet which ensures positive contact. Made to an exacting specification, this high-torque moving coil relay will respond to changes of 1 per cent in AC or DC voltage or current, and is adjustable between ±1 per cent and ±10 per cent.

This relay was developed for use in Austinlite Control Cubicles, as supplied to the G.P.O. and other telephone authorities throughout the world.

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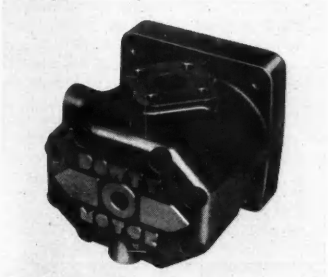
The carriage, which traverses at variable welding speed, has two traverse drive-wheels at one end of the tractor carriage, these wheels resting on the edge of the boiler shell. The tractor hangs down the boiler shell in a vertical position, and special adjustable guide and support rollers are mounted at the bottom end of the tractor. The traverse-wheels can be adjusted so that the machine can traverse around the inside of a boiler flue having a minimum diameter of 3 ft 1 in., and around the outside of a boiler shell having a maximum diameter of 6 ft. Welding speeds, which are infinitely variable from 2 to 25 ipm, are indicated on a tachometer fastened to the tractor.

A standard D.S. head, complete with control panel, swivel and rocker mounting, spool and mounting bracket, and hopper and mounting bracket, is fastened to a special mounting bracket attached to the top end of the tractor when it is hanging in a vertical position, the head being free to move vertically and angularly. The position of the nozzle in relation to the seam is maintained by a vertical guide-wheel running on the boiler end and a horizontal guide-wheel. This guide-wheel runs inside the plate when the machine is used for welding flues, and outside the plate when it is used for welding boiler shells. The machine, weighing 300 lb, is suitable for running on plates of from $\frac{1}{4}$ to $1\frac{1}{4}$ in. in thickness.

High-Performance Hydraulic Gear Motors

A range of hydraulic gear motors with outputs up to 30 hp, overall efficiencies up to 80%, and a speed range of 300 to 3000 rpm is announced by Dowty Hydraulic Units Ltd., of Aschurch, Gloucestershire. Basically akin to the well-known Dowty gear pumps and embodying many of their features, these new motors are inexpensive high-performance units providing high starting torque with smooth, positive control and complete reliability. Features include pressure balancing of the gears, simple cartridge-type construction, the use of plain bearings, and simplification of a minimum number of details.

The system of pressure balancing used is similar to that of Dowty gear pumps, in which inlet pressure is fed to the outer ends of one pair of bushes in the pump cartridge. O-ring seals limit the annular areas upon which the pressure acts, so that a controlled force, slightly greater than the load tending to "open" the bushes, holds them in contact with the gears. By this means, clearance is limited to the absolute minimum needed for lubrication purposes, preventing the internal leakage usual in gear-type units.



Plain bearings are used in preference to ball or roller journals, as they have been proved to have definite advantages, particularly for carrying heavy loads on a limited bearing area. Each bearing is lubricated by a metered quantity of fluid, which is afterwards ducted to a connection in the cover.

The motors are suitable for flange- or foot-mounting and, to increase their adaptability still further, a matching range of pipe connections is available. Elbow (female threads) and straight connectors (male threads) are designed to suit each motor in the standard range, with alternative thread sizes for each type of connector. Elbows can be placed in four different positions on each motor flange and, in conjunction with the other type of connector, will accommodate all normal pipe layouts. An outstanding advantage of these hydraulic motors is that it permits the use of a light, compact actuating unit in remote positions, without the complications of mechanical linkage. It also eliminates overloading problems, as these can be dealt with simply by incorporating a relief valve in the circuit to relieve excess pressure, thus eliminating the need for a slipping clutch or other form of safety device.

Surface Preparation for Protective Linings and Coatings used in Critical Service

(*Concluded from page 486*)

etch, G-40 grit (18 mesh) a 3·6 mil etch, G-25 grit (16 mesh) a 4·0 mil etch, and G-16 grit (12 mesh) an 8·0 mil etch.

Types of Abrasives:—

Natural silica sand is most commonly used for outside work where recovery is impossible. It has, however, its disadvantages, i.e., it may lack angularity and it may contact friable constituents of an alkaline nature, which break up and cling to the surface.

Crushed flint is extensively used in connection with metallizing, and owes its angularity to the conchoidal type of fracture common with flint. Sources vary, and those of very high purity leave a considerable amount of material embedded in the surface.

The use of crushed slag is comparatively new, but is gaining acceptance. It is produced from wet-bottom furnaces and is extremely angular with a low breakdown rate, though it leaves some material embedded in the surface. Tests show this material to be completely inert from the standpoint of corrosion.

Angular steel grit is widely used in cases where recovery is possible. It can be sized to give almost any desired etch and leaves nothing on the surface.

It is important to mention here the necessity for meticulous cleaning before application of the first coat of the sprayed system. Usually, the blasted surfaces and scaffolding are cleaned with an industrial-type vacuum cleaner, after which the surfaces to be primed are wiped until a clean white cloth is not discoloured when passed over the surface. Moreover, it is an accepted procedure to brush the first coat of a spray system over a newly blasted surface, on the assumption that any dust left on the surface will then be mixed with the liquid, greatly reducing the possibility of bridging microscopic areas.

Surface preparation and the lining operation should be considered as one job, under the responsibility of only one contractor. It has sometimes been suggested that two contracts should be awarded, i.e., one for surface preparation and the other for lining application. The division of responsibility between contractors for the effectiveness of the lining service, the variance in time lag permissible between blasting and priming operations, the method of and time required for removal of the abrasive, and the time necessary to free the surface to be protected from dust are all important factors. Consequently, in view of the difficulties likely to be involved, it is considered almost impossible to divide successfully surface preparation and lining into two separate contracts.

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ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Some Metal-Cutting Research Activities of the Production Engineering Research Association.

(From an article by the *Production Engineering Research Association of Great Britain*, 21 pages, 17 illustrations.)

MACHINING research can be broadly classified into analytical and practical investigations. The purpose of analytical investigations is to determine the precise nature of the mechanism of cutting and of the behaviour of the tool and machine tool. To facilitate analysis, the machining process is usually reduced to its simplest form by turning thin discs or planing narrow strips with elementary cutting tools. High-speed films, microscopic examination of the resulting chips, mathematical analysis, etc. are all used to build up a comprehensive picture of the complex phenomena that occur during machining. The practical machining techniques can then be modified, if necessary, in accordance with the clearer picture of metal cutting provided by the analytical investigations.

In practical investigations, on the other hand, data for immediate application in the workshop are obtained without a deliberate search for an explanation of basic phenomena. Controlled tests under conditions closely allied to practice are carried out to determine changes in tool performance with variations in tool geometry, cutting speed, feed, etc. The results of these tests can be applied directly to specific problems of great practical importance in the workshop.

This article consists of a short survey of some research into cutting tools carried out by the Production Engineering Research Association, together with a few examples of research results. As the cutting tool is only one of a large number of important factors in a machining process, brief reference is also made to investigations into factors such as machine tools and cutting fluids. Although attention is focused mainly on drilling, in order to illustrate the scope of the Association's research in a particular field, a few examples of results obtained in investigations of other types of tools are also included.

Artificial Insulating Joints for Mitigative Measures against Stray Currents.

By G. H. CANTWELL. (From *Corrosion, U.S.A.*, Vol. 13, No. 10, October 1957, pp. 18–20, 4 illustrations.)

ONE of the mitigative measures often used in stray-current corrosion work, either singularly or with other measures, is the insulating joint, which is a device for interrupting the flow of current on a metallic structure by inserting an insulator in the metallic path. Insulating joints are usually constructed in metallic sheathed cables by removing a small section of the sheath and replacing it with insulating tapes, and in metallic pipes by inserting an insulating gasket or ring between sections of the pipe.

The use of artificial insulating joints associated with the usual tests made prior to recommending permanent measures will eliminate the necessity of placing temporary insulating joints, or estimating the effect of an insulating joint. Also, since the equipment used for the artificial insulating joint is portable, the tests can readily be made from several locations.

In making electrical measurements pertinent to determining stray-current mitigative measures, it is often desirable to determine the effect of a proposed insulating joint at a predetermined location. By applying a direct-current source between the structure and the earth in the manner described in this paper, simulation of an insulating joint is achieved. Since the method is entirely electrical, the placing of temporary insulating joints for test purposes is eliminated. This method can be applied to any structure carrying stray d.c. earth currents.

In addition to simulating an insulating joint, the associated current and potential measurements are used to determine (1) the resistance to earth of the structure on each side of the point of application, (2) the potential to earth that would exist on each side of a permanent insulating joint, and (3) the potential across the permanent insulating joint. They also provide data for determining the resistance and current-carrying capacity for a bridging resistor.

Ni-Cr-B Brazing of a High-Temperature Alloy.

By G. AGGEN, R. A. LONG, and E. REYNOLDS. (From *The Welding Journal, U.S.A.*, Vol. 36, No. 8, August 1957, pp. 366s–372s, 7 illustrations.)

BRAZING for joining jet-engine components to operate at elevated temperatures has become significantly useful during recent years. Factors contributing to the use of brazing in these applications have been the development of furnaces capable of protecting surfaces to be brazed and the development and utilization of brazing alloys possessing good strength and oxidation resistance at elevated temperatures.

As described in this paper, a brazing investigation was conducted on sheet and bar specimens of A-286, an iron-base precipitation-hardening high-temperature alloy. Brazing was performed in a continuous-belt furnace under a dry hydrogen atmosphere. A Ni-Cr-B brazing alloy was used in joining all the specimens

The paper includes descriptions of the brazing furnace and brazing cycles required to obtain optimum joints in the specimens. Though the A-286 alloy contains about 2·0% titanium and 0·2% aluminium, it was not found necessary to plate the surfaces in order to obtain satisfactory joints. This is contrary to findings given in previously published papers in this field. A description of the simple and inexpensive surface preparation utilized is given in the paper.

The quality of the brazed joints was evaluated by metallographic examinations and mechanical tests. These tests include smooth- and notched-bar rupture tests at 1200°F and short-time tensile tests at room temperature, 1200, and 1300°F. Metallographic examinations were also made to determine the effects of the brazing alloy and the brazing time-temperature cycles on the microstructure of the high-temperature alloy. These were correlated with the results obtained from the mechanical tests.

Three types of specimens were evaluated by mechanical tests and metallographic examinations. These were as follows :

(1) *Surface-Brazed Specimens :* A thin coating of the brazing alloy was applied to the surface of fully machined V-notch and smooth-bar rupture specimens. The properties of these specimens were evaluated and compared with those of blanks which were subjected to identical machining and heat-treating cycles, but were not coated with the brazing alloy. Both sets were tested in three conditions of heat treatment performed after the brazing cycle. These and additional tests made it possible to determine the individual effects of the brazing cycles, the post-brazing heat treatments, and the presence of a thin coating of the brazing alloy on the properties of the A-286 alloy.

(2) *Butt-Brazed Bar Specimens* : Partially machined smooth-bar rupture and tensile specimens were butt-brazed, using several combinations of furnace belt speeds

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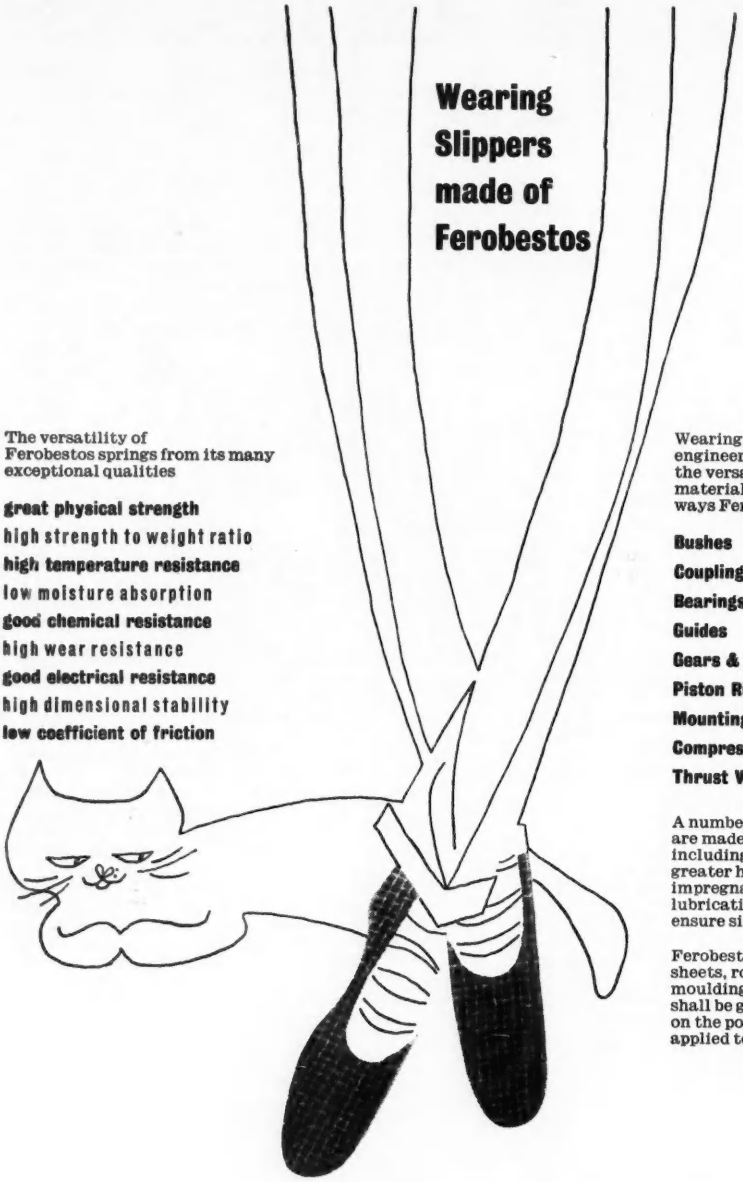

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and brazing clearances. The effects of these brazing variables were evaluated by metallographic examinations, rupture tests at 1200°F, and short-time tensile tests at room temperature, 1200, and 1300°F.

(3) *Double-Lap Sheet Specimens* : Sheet samples were prepared and brazed to form double-lap tensile specimens. Shear strengths of the joints were determined at room temperature, 1200, and 1300°F. These tests were performed on joints having two different clearances and after three post-brazing heat treatments.

The results of the investigation indicate that the brazing time-temperature cycle somewhat impairs the 1200°F rupture properties of the high-temperature alloy, but that these properties can be largely recovered by proper post-brazing heat treatment. Microstructural changes introduced at the surfaces of the base metal by the brazing alloy were shown to result in superior elevated-temperature properties. The strengths of the brazed joints were satisfactory, but not as high as those of the base A-286 alloy.

Dynamic Loads on the Teeth of Spur Gears.
By S. L. HARRIS. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, October 25, 1957, 16 pages, 22 illustrations.)

IN the analysis described in this paper of the restricted case of a pair of spur gears isolated from external stimuli, theory suggests three internal sources of vibration, i.e., (1) periodic variations in the velocity ratio due either to running the gears above or below the designed load, or to small manufacturing errors ; (2) period variation in the tooth stiffness ; and (3) non-linearity in tooth stiffness. The amplitudes of vibrations caused by (1) depend on damping, while those caused by (2) or (3) will occur only if the damping is below a limit estimated at 0·07 critical damping. Damping currently reported for tests on steel gears is about 0·1 critical, but might well be less.

Dynamic tooth forces and amplitudes of vibration were found from photo-elastic stress patterns of model gears with both small and large errors. The more accurate gears showed only vibration caused by variation in the velocity ratio, because the damping was too great for the other modes.

Information on damping is insufficient for satisfactory prediction of dynamic increments. If the damping in any gears were to fall to 0·07 critical, the increment, instead of having a small value, might equal the applied load, irrespective of any errors, and this might prove disastrous.

It is concluded that such a theoretical treatment can only serve to indicate possible modes of vibration, and whether they occur in practice must be determined by experiment. If the relationship between errors and vibration is to be understood, the errors should be measured under load. Only thus can the combined result of manufacturing errors and deflections be found.

Zinc Telluride as a Semiconductor.
By J. HORAK, M. MACHOVEC, and F. KOSEK. (From *Czechoslovak Journal of Physics, Czechoslovakia*, Vol. 7, No. 4, 1957, pp. 468–475, 6 illustrations.)

As described in this paper, zinc telluride was synthetized in quartz from very pure samples of zinc and tellurium. The Debye-Scherrer method was used to revise the tabulated values of the lattice constant, for which the value of 6·085 Å was found by extrapolation of the back-reflection method. The conductivity of zinc telluride as a function of the temperature was measured on evaporated thin films, the structure of which does not differ from the structure of the bulk material. The films were evaporated in a vacuum of the order of 10^{-6} mm Hg on copper contacts. The copper was electrolytically deposited on silver burned onto coated porcelain. The current-voltage dependence on the Cu-ZnTe-Cu contacts was purely ohmic, eliminating the production of barrier layers at the contact of the copper with the zinc telluride.

The conductivity of the heated specimens was found to be much higher during the first measurement than during subsequent measurements, and decreased when the specimens were heated. For this reason, the samples were heated for 5 hr at a temperature of 120°C in a paraffin-oil bath, during which time the conductivity approached a certain limiting value. The value of the conductivity was measured in the range between 0 and 140°C, and the activation energy was calculated in this temperature range.

The thermal e.m.f. was determined for samples obtained by pressing zinc telluride powder at a pressure of about 30,000 kg/cm² and sintering at a temperature of 1200°C for 6 hr, using rod-like copper electrodes pressed against the sample being measured. It was found that the warm contact always had negative polarity, and the average value of the thermal e.m.f. in the limits 20 to 50°C was around 0·5 mV/°C. It was thus uniquely determined that the specimens exhibit a *p*-type conductivity.

On the basis of the properties of the chalcogenides ZnO and ZnS already studied and some results not yet published concerning the properties of ZnSe and the given properties of ZnTe, the production of *p*- and *n*-type semiconductors is discussed for all chalcogenides of zinc on the basis of the assumed partial thermic dissociation of the corresponding chalcogenides and on the basis of the various volatilities of the elements forming the chalcogenides. The component of the chalcogenides, to which a lower boiling point corresponds in the elementary form, flows away more easily during the preparation of the samples (sintering, recrystallization, heating, etc.) and thus leads to a non-stoichiometric relation between the elements forming the chalcogenides. The excess of one of the components then determines the type of conductivity. Zinc oxide must be an *n*-type semiconductor, and zinc telluride a *p*-type semiconductor. This scheme is supplemented by the concept of the diffusion of the ions (or atoms) in the crystal lattice. This concept is in good agreement with the experimental results of other authors.

Brushless Air-Cooled Aircraft a.c. Generators.
By R. E. SMITH. (From *Applications and Industry (A.I.E.E.), U.S.A.*, No. 32, September 1957, pp. 189–192, 6 illustrations.)

THE quantity and complexity of electrical apparatus on aircraft have increased so much that maintenance of this apparatus has become a serious problem. On future aircraft, which will have even more complex requirements for electrical equipment, programmes must continue to be initiated to provide more reliability and simplicity, if aircraft are to be kept in flying readiness. Generators, the source of electric power for the aircraft, are among the most important components of the electrical system.

Some of the construction details and the means by which a brushless air-cooled aircraft a.c. generator can contribute to the reliability and simplicity of an electrical system are analysed in this paper, and include details of generator design, rectifier characteristics, and exciter characteristics.

The data presented in this paper have led to the following conclusions :—

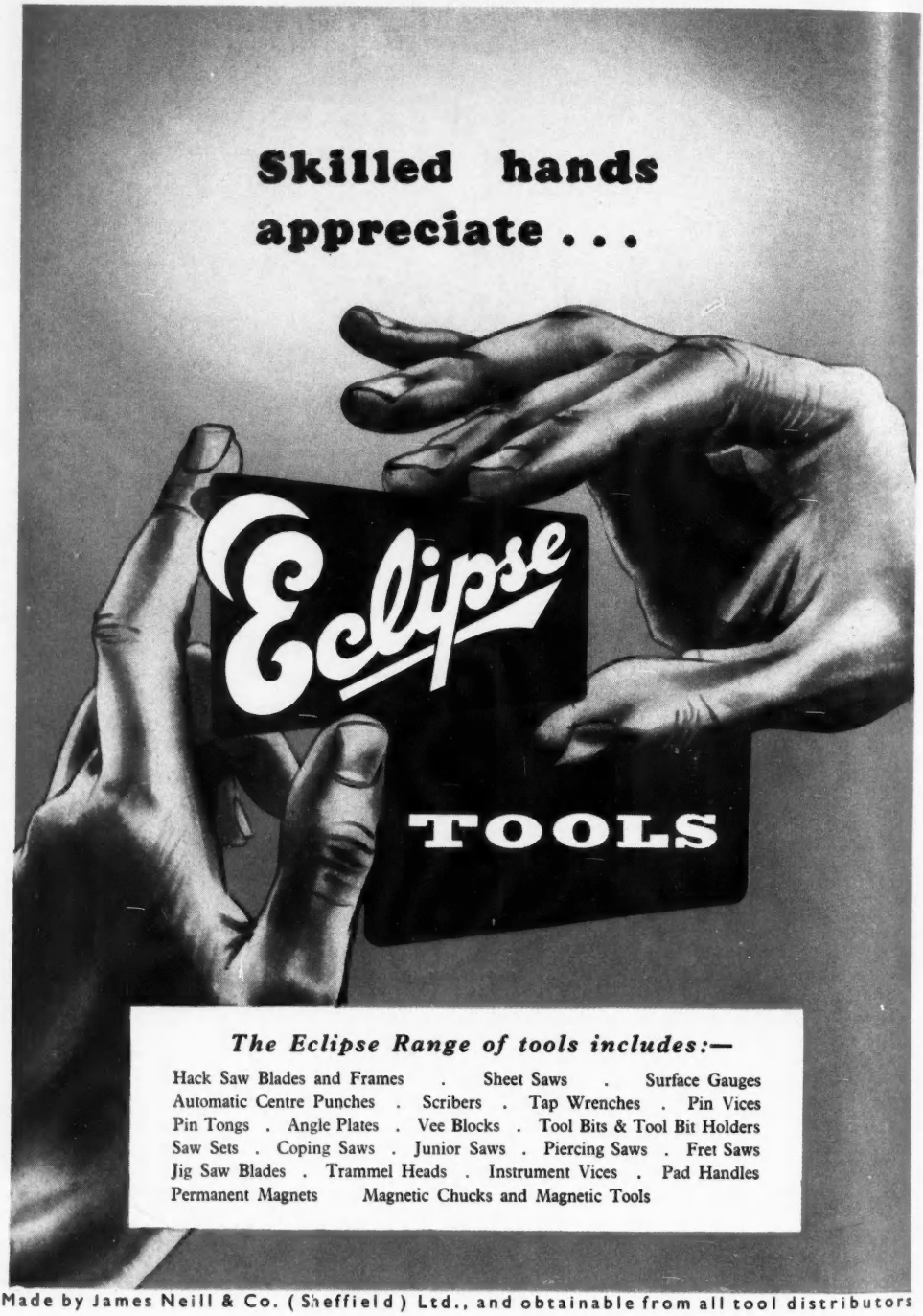
(1) A brushless generator is more nearly environment-free than a conventional generator.

(2) A brushless generator will have more consistent performance than a conventional generator.

(3) Maintenance is simplified, because of the reduced number of parts, compared with conventional generators.

(4) Reliability has been increased by elimination of items such as brushes, commutators, and slip-rings, which can have inconsistent performance, and by incorporating simple provisions for ensured voltage build-up.

(5) A brushless generator is more easily matched to the voltage regulator, because the range of excitation required by its a.c. exciter over the temperature range is much less than that required by the d.c. exciter of a conventional generator.



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New Materials, Processes, and Equipment

FULL-PHASING ONE-WAY CLUTCH

In the Borg-Warner full-phasing one-way clutch announced by Borg-Warner Ltd., of Letchworth, Herts., a number of small cams are held in two circular cages by means of a ribbon spring. When the clutch is mounted in the annular space between two cylindrical races, a drive may be transmitted through the clutch from one race to the other in one direction only. During rotation in the opposite direction no drive is transmitted. The operational details of the clutch are shown in Fig. 1.

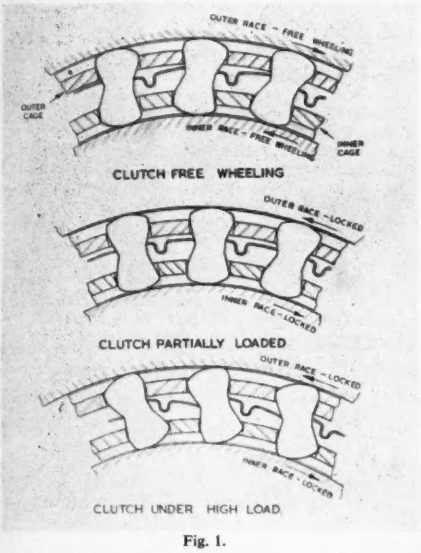


Fig. 1.

A unique feature of the design is the use of two flanged cages, which ensure that the sprags are fully phased. Thus, all sprags work in unison, each carrying its full share of the load. This is particularly important where conditions of shock or torsional oscillation are present. Moreover, the units are compact and are capable of transmitting high torque with little or no backlash.

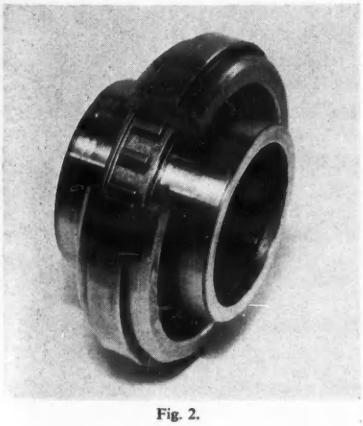
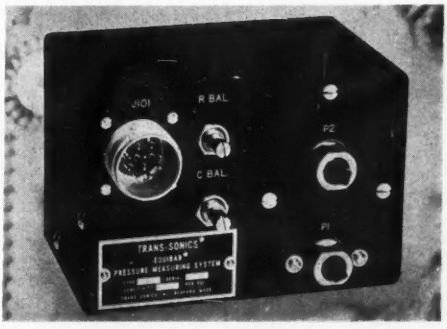


Fig. 2.

The clutch, which is shown mounted between inner and outer races in Fig. 2, is ideally suitable for all applications where a unidirectional drive is required, particularly when weight and space considerations are important. Several sizes are available, and typical applications include aircraft gas-turbine starter drives, helicopter rotor drives, automatic transmissions, hydraulic torque converters (static retention), automatic front-wheel drives for military vehicles, household washing-machines (enabling the spin-dry drive to overrun the slower washing drive), and agricultural-machine drives (preventing a heavy towed machine from "taking charge" of the prime mover).

HIGH-SPEED GAS-PRESSURE TRANSDUCER

The "Equibar", a gas-pressure transducer capable of high-speed measurement of pressures from 10^{-3} to 15 psi, has been developed by Trans-Sonics, Inc., of Burlington, Massachusetts. In addition to having an input dynamic range of over 10^6, the "Equibar" has an extremely deep and stable null which does not change with voltage, frequency, ageing, or environmental conditions. Zero shift is so low that the $\pm 2\%$ accuracy can be expressed as a percentage of the pressure reading, rather than of full scale. Its stability, fast response, high voltage output, ruggedness, and compactness make this instrument useful in vacuum measuring systems, servo-control systems, recording and telemetering systems, and aircraft instruments.

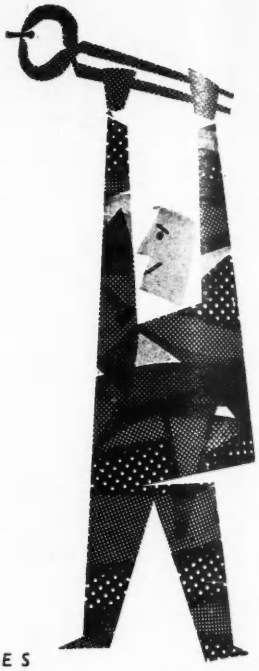


As an airborne transducer, the device provides up to 35 V output for direct drive of telemetering circuits, and has an acceleration sensitivity of less than 0·015% of the operating interval per *g* in any direction. With a natural frequency higher than 3000 cps, it has sufficiently fast response for servo-controlled altitude-hold systems, rate-of-climb indicators, and air-speed or Mach-number instruments in both missiles and aircraft.

In the laboratory, it can be used for low-pressure studies and for absolute vacuum measurements down to 10^{-6} psi. It can sense transient changes which may escape detection by other vacuum measuring devices, and can be used in the accurate control of low-pressure systems and in the precise metering of gas flow. As a production calibration device, it can indicate the instant in time when a changing pressure equals a fixed pressure and can thus serve to define calibration points for pressure transducers. It can also be used as a leak detector in testing pressurized systems and evacuated components.

The "Equibar" consists of a pressure-sensing element, a bridge circuit with null adjustments, and a cathode-follower output circuit, all mounted and shielded

dynamic technique



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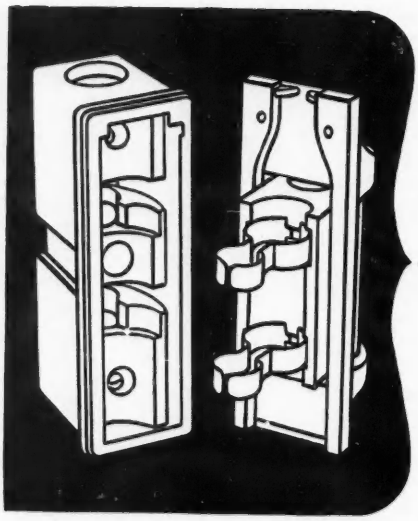
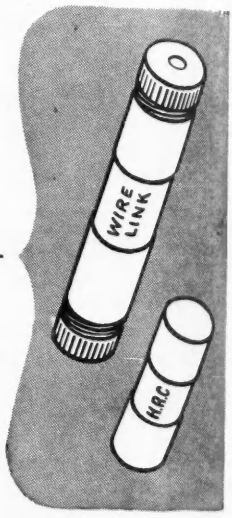


The Two-In-One Unit

REWIRABLE OR H.R.C.

One of the outstanding features which have made the new "H" Type Slydlok Fuse universally popular is its ability to accept either Rewirable Fuselinks or H.R.C. Cartridge Fuses without any modification to the base or holder, a simple and economical arrangement which saves time, trouble and tempers.



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dmEW83

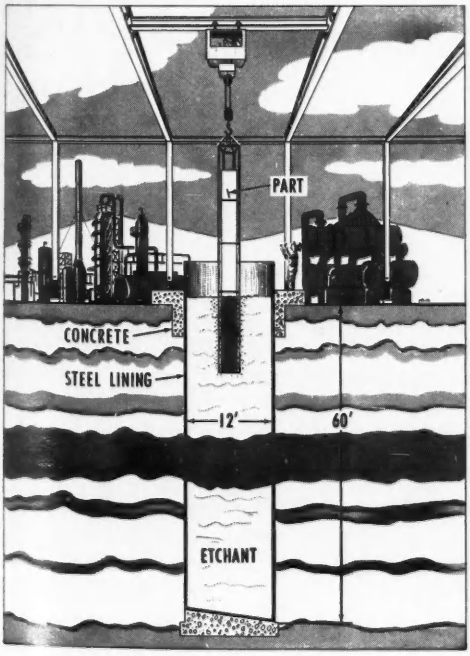
in a compact case. The sensing element consists of a stretched metal diaphragm which moves between two capacitive electrodes as pressures on opposite sides of the diaphragm vary. Small diaphragm deflections change the capacitance of two bridge legs and cause variation in the bridge output. The pure reactance and linearity of this sensing element cause suppression of quadrature and harmonic components and make the bridge null independent of power-supply waveform, while the cathode-follower circuit reduces output impedance to a few hundred ohms.

VERTICAL TAPERING TANK FOR CHEMICAL MILLING

Stated to be the largest in the world, a new vertical tapering tank for chemical milling is now in operation at the Manhattan Beach Plant of the United States Chemical Milling Corporation. The tapering tank, which extends 60 ft underground, was installed with its accompanying facilities to meet the increasing demand for extremely long tapered structures in the design of advanced aircraft. As one of the most valuable applications of chemical milling is the production of smooth tapers on long parts, and as the taper is controlled by the rate of immersion into the solution, the tank holding the etchant must be deep enough to hold the entire tapered section. The installation of this new tank now makes it possible to taper parts as large as 55 ft in length and 11 ft in diameter.

Although the exterior of the tank was coated with a preservative before it was fabricated, additional protection is used in the form of an anodic system to prevent any external electrochemical reactions from eating away the tank shell. For this purpose, four 25-lb magnesium bars are attached 90 deg. apart on the exterior of the tank, and are connected electrically and grounded to provide the necessary protection. No protection is needed for the interior of the tank, since the chemical solution used as the etchant for aluminium acts as a preservative for steel.

Since the taper angle is controlled by the rate of immersion, a precise mechanical control system must be used to immerse the part into the solution at a uniform and predetermined rate. Extrusions and other parts are lowered into the tank with an overhead hoist. A wide range of immersion speeds is needed to produce all possible taper angles, and, as requirements could not be met by existing electrical and pneumatic systems, a special hydraulic drive system has been designed, utilizing a variable-displacement hydraulic motor to power the overhead hoist. The result is a continuous range of immersion speeds, varying from 0 to 120 fpm.



UNIVERSAL PUNCHING PRESS

The universal punching press model 57 manufactured by Georg Lindemann, of Schoetmar-Lippe, Germany, is a combination of eccentric press and a tube and pipe notching machine. Two models are available, of 22 and 32 tons capacity respectively. These machines will handle tubes up to about 6 in. diameter and are also suitable for most punching and cropping operations.

These presses feature a two-way stroke, the tools cutting in both directions, starting from the interior of the tube towards the exterior, producing very clean cuts and avoiding tube distortion. In addition to straight, mould, and bevel (up to 45 deg.) cuts, any round, square, sectional, and oval holes may be cropped from the tube without difficulty.

For tube notching, a special toolholder is available, permitting rapid change of different tools and capable (depending on the tube concerned) of accommodating up to six different tools simultaneously. For standard punching and cropping work, the special toolholder is replaced by a standard work-table and conventional punching and cropping tools. The press itself acts as an ordinary eccentric type of press.

AUTOMATIC THICKNESS-MEASURING EQUIPMENT

The " Vidigage ", developed by Branson Instruments Inc., of Stamford, Connecticut, measures thickness automatically and, in conjunction with automatic detection and recording attachments, can be used to spot changes in the thickness of metals and plastics as small as 0·05%.

In operation, a piezoelectric transducer, excited by an electronic sweep oscillator, vibrates over the range of frequencies generated by the oscillator. When the transducer is placed in contact with one surface of the material under test, with a thin film of liquid as a coupler, continuous ultrasonic waves pass into and through the material and are reflected back from the first discontinuity they encounter, either an internal flaw or the opposite surface. Each thickness has its own natural resonant frequency. When the continuously varying frequencies of the ultrasonic waves equal the resonant frequency of the part, or are a harmonic of this frequency, there will be a considerable increase in the amplitude of the vibrations in the material. This resonance condition produces an increase in the plate current of the oscillator tube.

The horizontal base line on the face of a cathode-ray tube represents the frequency-sweep range. The increase in oscillator-plate current produced at resonant frequencies is amplified and applied to the vertical-deflection coil of the tube, on which thickness resonance in the material is therefore indicated by a vertical line. Scales calibrated for thickness, placed in front of the tube, enable the operator to read the thickness of material corresponding to the position of the vertical line on the scale. Resonance indications are obtained at the fundamental frequency and at harmonics of this frequency. Direct-reading scales for harmonics permit measurement of thick sections instantaneously, without calculations. Harmonic scales have several parallel calibrated lines, thickness being read on one line and checked on the next. Typical thickness ranges on direct-reading scales are 0·006 to 0·036 in., 0·028 to 0·237 in., and 0·435 to 0·925 in.

Discontinuities in the material under test will reflect the ultrasonic waves back to the transducer and modify the trace on the cathode-ray tube. Lack of bond in clad

THE *Bison*

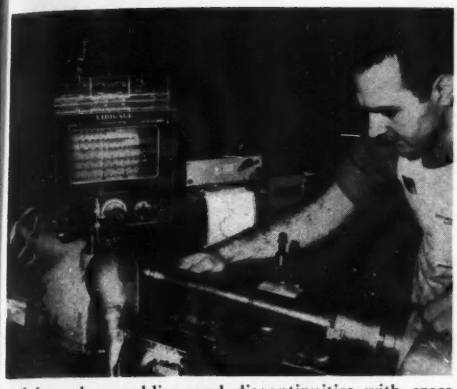
FOR PRECISION PROFILE CUTTING

THE BISON profile cutting machine combines versatility with a high degree of accuracy. It can carry up to three cutting heads and is available in two main cutting widths; also, the longitudinal cut can be extended by adding extra sections of track. Interchangeable tracing heads enable work to be carried out from wood or steel templates or drawings, making it suitable for repetition work or the one-off job. Whether using acetylene, propane or coal gas, precise regulation of the cutting speed ensures the highest degree of accuracy and eliminates further preparation before welding. The Bison is giving perfect results on a wide variety of work in industry. For further information please contact your nearest British Oxygen sales office.

Our illustration shows the Bison in action at the works of Messrs. Sale, Tilney & Company Ltd., Wokingham, Berks.

BOC BRITISH OXYGEN

British Oxygen Gases Ltd., Industrial Division, Spencer House, 27 St. James's Place, London, S.W.1.



and brazed assemblies, and discontinuities with cross-sectional areas of at least 0·1 sq in., appear as sudden thickness changes on the " Vidigage " scale. For detecting tightly closed laminar flaws, and weak bonds in clad or roll-bonded sections, high frequencies (between 10 and 25 Mcs) are recommended.

An "automation converter " attachment, which connects with the " Vidigage " through a single cable and plug, detects the presence of a strong resonance signal within preset gating limits. The location and width of the gate can be adjusted to coincide with the allowable thickness range of the material. Gating limits are marked on the screen by brightening the base line within the gate. A strong signal within these limits will trip a relay, which in turn actuates other convenient attachments such as audible alarms, marking devices, or automatic sorting attachments.

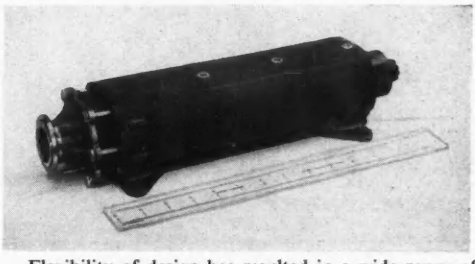
Multiple gating circuits can be used. They do not interfere with each other and make it possible to sort material into a number of groups according to thickness. High and low thickness tolerances can be established, and material sorted automatically into three categories, i.e., undersize, correct size, and oversize. Similarly, the output of the gating circuit can be applied to a potentiometer-type strip chart recorder, where the deflection of the recording pen will depend on the distance of the resonance indication from one edge of the gate. Extremely high accuracies (as high as 0·02%) have been achieved with the automatic recording attachment, which is most useful when the thickness range to be recorded is limited. Alternatively, the signal, after amplification, may be used to control machining processes, or to make corrective adjustments. Thicknesses down to 0·005 in. can be inspected.

CAM-PISTON AIR MOTORS FOR HIGH-TEMPERATURE APPLICATION

A range of air motors, capable of operating at temperatures above 1000°F without conventional lubrication or cooling, has been developed by the AiResearch Manufacturing Division of the Garrett Corporation, of Phoenix, Arizona. These motors are capable of withstanding the extremely high temperatures found in missile and supersonic flight at speeds of Mach 2 and more, and prospective uses include power actuation for thrust reversers, control surfaces, and exit nozzles.

The cam-piston motor is a positive-displacement, fluid-drive unit which uses hot compressed air. Output is nearly linear with inlet pressure, permitting maximum efficiency over a wide range of operating conditions. In addition, maximum power/weight ratio and high starting and braking torque have been obtained by designing for maximum displacement per revolution. Other features include rapid acceleration and reversibility, low air consumption, and low rotational speeds (100 to 2500 rpm), eliminating the need for reduction gears in most applications and minimizing problems of excessive wear without lubrication, high rotational stresses, and overspeed control. A typical model stands about 3 in. high and is about 13 in. long, weighing 22 lb and having an output of 18½ hp at 1200 rpm and 200 psig air pressure.

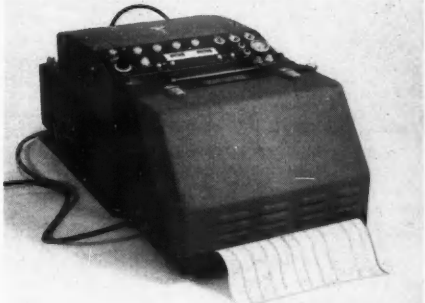
Operation of a typical motor is as follows :—A force resulting from a pressure differential across the piston is exerted in an axial direction of piston travel. Because of the stationary position of three equally spaced cam-follower bearings, the piston is forced to rotate through 60 deg. during a full power stroke. Since the piston is ball-splined to the output shaft, torque is transmitted to the shaft. At the end of the piston stroke, the pressure differential is reversed, providing a double-acting piston which reciprocates three times per revolution. The unit contains three pistons, providing for a total of eighteen power strokes per revolution, equally distributed at 20-deg. intervals. The motor provides the equivalent number of strokes per revolution, with uniform output torque, as a conventional four-cycle 36-cylinder engine.



Flexibility of design has resulted in a wide range of sizes, with power ratings of 1 to 300 hp, depending on the pressure supply available. Additional flexibility of configuration with respect to the length/diameter ratio can be provided by varying the number of pistons, as well as piston diameter and stroke. When coupled with a ball screw, which may retract within the full length of the motor shaft, the unit also has a wide range of applications as a compact high-performance linear actuator in high-temperature pneumatic power-control systems.

DIRECT-WRITING MAGAZINE ATTACHMENT FOR STANDARD OSCILLOGRAPHS

A new direct-writing magazine, which attaches to standard oscillographs and provides developed and dried photographic records as rapidly as instrument records data are produced, is announced by the Consolidated Electrodynamics Corporation, of Pasadena, California. Designated the " 5-036 Datarite Magazine ", it represents the first " systems " approach to oscillographic instrumentation and, by using an exclusive high-speed system of " flash-processing ", it chemically develops an oscillogram at speeds up to 25 in. per second. Furthermore, it provides continuous and practically instant



what, no nuts? . . .

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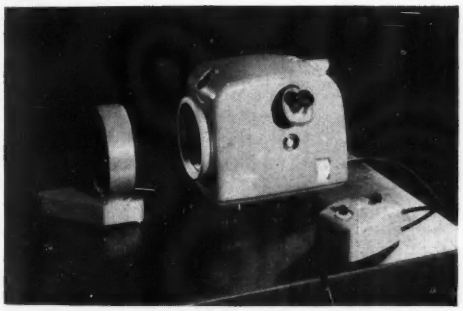
access to the record and furnishes a completely dried oscillogram which can be examined in full daylight while the test may be still going on.

The new unit is basically designed for direct attachment to the Consolidated Type 5–119 recording oscillograph, and is completely interchangeable with the standard magazine without modification. Installation can be effected in a few seconds. Imparting new versatility to the use of conventional silver-halide emulsion recording papers, it permits the use of a wide range of materials and yields excellent record contrast. With a nominal capacity of 400 ft of 12-in. paper, it provides high information capacity for long recording runs and has the great advantage of eliminating the principal drawback of the time delays occasioned by wet-processing of records in a special darkroom or tank.

ALIGNMENT INTERFEROMETER

Stated to be the most sensitive and accurate measuring instrument ever devised, a new alignment interferometer developed by the Bausch and Lomb Optical Company, of Rochester, N.Y., is capable of measuring changes in angle of arc to an accuracy of no less than 3 microinches. The new interferometer comprises two separate units, i.e., the main body or light-source and the mirror. In operation, a ray of light is emitted from the main unit and reflected by the mirror, which may be located as far away as 14 ft. These waves of light act as " rulers ", by means of which exceedingly small variations may be measured.

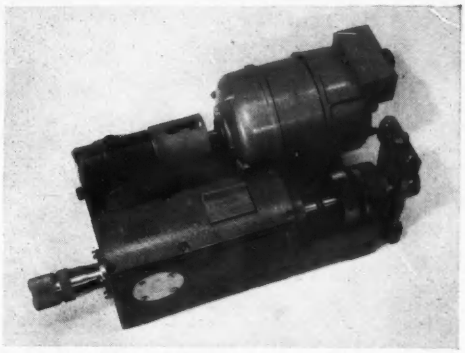


Readings are obtained by setting the main body and mirror units to zero alignment. This is accomplished by setting the graduated scale of the instrument to zero and adjusting the controls until three parallel dark lines can be seen across a bright green field. When the mirror unit is moved, the changing angle of the reflected rays of light causes many more dark lines to crowd into the field of view. Once the change of angle has been completed, the operator merely re-adjusts the graduated scale control-knob until the three original parallel lines are returned, thereby resetting the instrument to zero. A reading of the change of angle, in seconds of arc, may then be made directly from the scale.

Use of the instrument is not restricted to flat-bed surface measurements, as it can be used in any situation where ultra-precision is required, i.e., resting on its base, side, or end, for measuring the alignment of such items as jigs, fixtures, etc.

VARIABLE-STROKE PRECISION METERING PUMPS

Developed for plant and laboratory use and suitable for most liquids, the new range of DCL " M " pumps announced by The Distillers Company Limited, of Great Burgh, Epsom, are precision metering pumps in which variations of flow rate are obtained by altering the stroke, which is adjusted by means of a micrometer screw. These variations can be effected with the pump stationary or running. To ensure trouble-free service with minimum maintenance, oil-bath lubrication is used



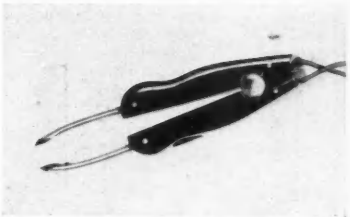
for the driving and variable-stroke mechanism. The pump and valve bodies are of 18/8 stainless steel, and the suction and delivery ball-valves, which are duplicated to ensure higher efficiency, are of " non-corrodible " steel. Readily interchangeable pump heads in standard materials are available but, if required, head assemblies of special materials can be provided to meet difficult chemical conditions.

These pumps are available with different plunger sizes, providing a range of six standard capacities, from 0 to 0·16 gph with a maximum working pressure of 2400 psi, up to 8¼ gph with a maximum pressure of 50 psi.

TWIN-ELECTRODE MULTI-PURPOSE SOLDERING TOOL

Based on the principle of heating the work directly, instead of the conventional method of initially heating a mass of metal, from which a small amount of heat is then transferred, the Victor twin-electrode multi-purpose soldering tool, model V.360, announced by the Allied Distributing Corporation Ltd., of London, W.1, is designed for maximum speed of operation and elimination of heat losses, " dry " joints, and oxidation.

Direct heating of the work is achieved by gripping it with the twin arms of the tool. At the ends of these arms, which act as leads for the electric current, are special electrodes which convey the heat directly to the work. Adjustable stems and electrode holders, together with electrodes of different shapes, enable all types of soldering to be carried out with a single tool. If required, the earth-return lead permits the use of one arm only. Low-voltage operation (2 to 8 V, a.c. or d.c.) via a battery or transformer ensures safety and maximum economy.



Soldering is effected very simply by gripping the joint in the arms, applying the solder, and pressing a button, causing the work to heat up immediately and the solder to run. The button is then released, breaking the heating circuit, and the joint held for a few seconds, so as to permit the solder to harden. Except in those cases where the metal has previously been oxidized, no precleaning of the work, even including removal of oil, is necessary. Furthermore, dismantling of work requiring soldering is reduced to a minimum, as the twin arms provide extra freedom of action, even in hitherto inaccessible joint locations.

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The LOCKHEED *'Hydroloc'* VALVE

locks a hydraulic slave unit securely in any position without line pressure

This simple and effective unit creates a hydraulic lock in one end of the slave cylinder until the other end is fed under pressure, when the 'lock' is automatically released. Even if the slave cylinder is released under a heavy reactive load, the 'Hydroloc' prevents judder.

The 'Hydroloc' is simple, very easy to install, and needs no mechanical connections. If the load is always 'one-way' such as in a slave cylinder with a spring-loaded return, one single-type 'Hydroloc' is sufficient. If the load changes direction, the twin 'Hydroloc' valves, or two single valves, hold the piston in both directions.

'Hydrolocs' are available immediately in ¼" B.S.P. and for pressures up to 2000 p.s.i.

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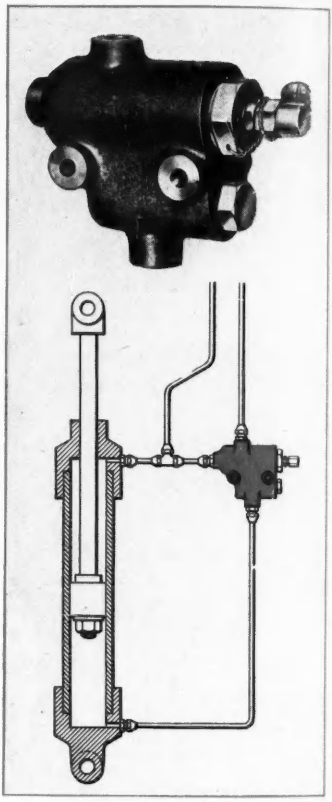

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NEWS OF THE MONTH

PERSONAL

Mr. Benjamin R. Beebee has been appointed London manager of Henry Meadows Ltd., Wolverhampton, at their office at 37/41 Bedford Row, London, W.C.1.

Sir George Beharrell has resigned from the Presidency of the Dunlop Rubber Co. Ltd., but has consented to act as an honorary consultant. His colleagues placed on record their appreciation of his distinguished part in the history and development of the Dunlop Group. **Lord Baillieu** has resigned his Chairmanship, but agreed to remain on the Board and to succeed Sir George Beharrell as President of the company. **Mr. G. E. Beharrell** has been elected chairman of the Board and will continue to act as chief executive of the company. **Mr. John H. Lord** and **Mr. R. M. Geddes** have been appointed managing directors, and **Mr. T. E. Peppercorn** an executive member of the Board.

Mr. David Brooke has been appointed chairman, **Mr. C. W. Mustill** managing director, **Mr. Frank Cooke** sales director, **Mr. E. Gudgeon** works director, and **Mr. E. C. King** director and secretary, of Jackson Boilers Ltd.

Mr. Douglas Brown has been appointed marketing manager of Black & Decker Ltd., Harmondsworth, Middx.

Mr. K. J. Clarke, A.M.I.E.E., has been appointed manager of the Sheffield district office of The British Thomson-Houston Co. Ltd., in succession to **Mr. C. A. Russell,** who has retired after 45 years' service.

Rear-Admiral N. E. H. Clarke, A.M.I.Mech.E., has been appointed Deputy Director of Dockyards (Administration), Admiralty, London, S.W.1, in succession to **Rear-Admiral L. A. B. Peile, C.B., D.S.O., M.V.O.,** who has been appointed Admiral-Superintendent of H.M. Dockyard, Devonport.

Mr. H. Darnell has been appointed chief engineer of Workington Iron & Steel Company, a branch of The United Steel Companies Ltd., 17 Westbourne Road, Sheffield 10, to succeed **Mr. G. F. Strang,** who has left the company to take up another appointment.

Mr. H. T. E. Goldup, C.B.E., M.I.E.E., a director of Mullard Ltd., Mullard House, Torrington Place, London, W.C.1, and of Mullard Equipment Ltd., has been elected President of the Institution of Electrical Engineers. Mr. Goldup is also chairman of the Ministry of Supply College of Electronics at Malvern, and serves on various committees of the Radio Industry Council, the British Standards Institution, and other organizations connected with the electronics industry.

Mr. F. G. Goodenough, managing director of Goodenough Pumps Ltd., has been elected a director of Power Installations Ltd., Leicester.

Mr. H. B. Gough, Assoc.I.E.E., has been appointed sales manager of the X-ray and scientific apparatus department of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17. **Mr. R. S. Clark, A.M.I.Mech.E.,** has been appointed superintendent of the scientific apparatus department at Barton Dock Road Works.

Mr. H. G. Higginson, general sales manager of Birflo Controls, has recently taken up his appointment with Birfield Industries Ltd., Stratford House, London, W.1.

Dr. H. S. Hirst, technical department manager of the I.C.I. Billingham Division, has been appointed general manager of the £100 m. projected Severnside site of Imperial Chemical Industries Ltd., in succession to **Dr. H. G. Reid,** who has been appointed President and director of Imperial Chemical Industries Ltd., New York, N.Y. Dr. Reid succeeds **Mr. K. W. Palmer,** who is returning to the U.K. to become a joint managing director of the newly formed heavy organic chemicals division, which has been formed as part of the Billingham division of I.C.I.

Mr. W. R. R. Husser, a director of A.B.O.E. (Export) Ltd., a subsidiary of The Brush Group, has joined the Board of United Construction Machinery Co. Ltd., Horton Parade, West Drayton, Middlesex.

Mr. G. M. Keightley has been appointed manager of the British Sales Division of Consolidated Pneumatic Tool Co. Ltd., 232 Dawes Road, London, S.W.6. **Mr. R. E. Bayliss** has been appointed assistant manager.

Dr. A. E. Laurence has been appointed manager of the Central Research Department at the European office of Minnesota Mining & Manufacturing Co. Ltd., 3M House, Wigmore Street, London, W.1.

Mr. F. C. Lucas has been appointed Head of the Industrial Sales Department of the British Thomson-Houston Co. Ltd., Crown House, Aldwych, London, W.C.2, in succession to **Mr. R. A. R. Bottone, M.I.E.E.,** who recently retired.

Sir Andrew McCance, F.R.S., chairman and managing director of Colvilles Ltd., Glasgow, has been invited to continue as President of the British Iron and Steel Federation for 1958. **Mr. Lewis Chapman,** chairman of William Jessop & Sons Ltd., Sheffield, has been appointed President-elect.

Vice-Admiral Sir Frank Mason, K.C.B., following his recent retirement as Engineer-in-Chief of the Fleet, has accepted a position as consultant to the management of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17.

Lt.-Col. C. P. Milway, M.C., E.R.D., A.M.I.C.E., A.M.I.Mun.E., has been appointed chief engineer to the Ministry of Health and Local Government of Northern Ireland, in succession to **Mr. R. D. Duncan, O.B.E., B.Sc., M.I.C.E., M.I.W.E.,** who has retired

Mr. Eric E. Pratt has been appointed commercial manager of the Electronics and Equipment Group of The Plessey Co. Ltd., Ilford, Essex.

Sir Harry Railing, D.Eng., Hon.M.I.E.E., chairman and joint managing director of The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2, has retired, but has agreed to remain a member of the Board. Sir Harry, an electrical engineer of great distinction, has played an outstanding part in the affairs of the company for nearly 52 years. He was largely responsible for the development of the heavy-engineering side of G.E.C.

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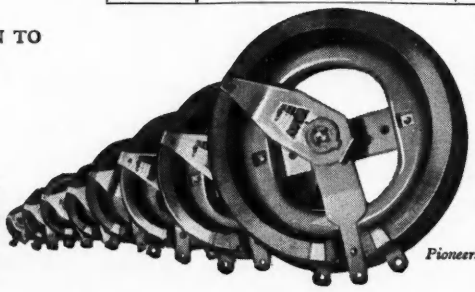
	L.25	L.50	L.75	L.100	L.150	L.225	L.300	L.500
1	—	7.07	8.66	10.00	12.50	15.0	17.3	22.3
2	3.54	5.00	6.12	7.07	8.66	10.6	12.2	15.8
3	2.89	4.08	5.00	5.75	7.07	8.66	10.0	12.9
5	2.24	3.16	3.86	4.77	5.48	6.71	7.75	10.0
7.5	1.82	2.56	3.16	3.65	4.47	5.48	6.32	8.17
10	1.58	2.24	2.74	3.16	3.88	4.74	5.48	7.07
15	1.29	1.83	2.24	2.58	3.16	3.87	4.47	5.78
25	1.00	1.41	1.73	2.00	2.45	3.00	3.46	4.47
50	.707	1.00	1.23	1.41	1.73	2.12	2.45	3.16
75	.578	.818	1.00	1.15	1.41	1.73	2.00	2.58
100	.500	.707	.866	1.00	1.23	1.50	1.73	2.23
150	.408	.575	.707	.818	1.00	1.22	1.41	1.82
200	.354	.500	.612	.707	.866	1.06	1.22	1.58
350	.268	.378	.463	.535	.655	.803	.926	1.19
500	.224	.316	.388	.447	.548	.671	.775	1.00
1,000	.158	.224	.274	.316	.388	.474	.548	0.708
1,500	.129	.183	.224	.258	.316	.387	.447	.578
2,500	.100	.141	.173	.200	.245	.300	.346	.448
5,000	—	.100	.123	.141	.173	.213	.245	.315
7,500	—	.081	.100	.115	.141	.173	.200	.258
10,000	—	—	—	.110	.125	—	.173	.224
15,000	—	—	—	—	—	—	—	.163



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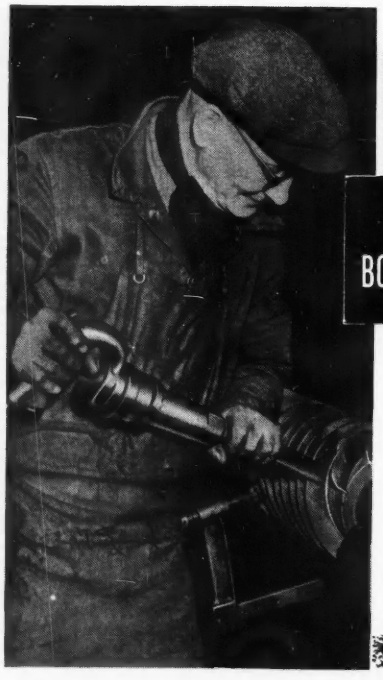

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In 1944, Sir Harry became President, and in 1953 he was elected Honorary Member of the Institution of Electrical Engineers. In 1955 he was elected President of the British Electrical Power Convention. In 1952, he was elected President of B.E.A.M.A., and in 1954 Vice-President of the British Electrical Development Association.

Mr. Leslie Gamage, M.C., M.A., F.C.I.S., vice-chairman and joint managing director, has been elected chairman and managing director of The General Electric Co. Ltd. as from November 1st. Mr. Gamage joined G.E.C. in 1919 and has been a member of the Board since 1925, when he assumed responsibility for the company's export business. It is largely due to his initiative and drive that the export business of G.E.C. now exceeds £24,000,000 per annum.

Dr. James Reekie, B.Sc., Ph.D., A.M.I.E.E., has been appointed chief engineer of Semiconductors Ltd., Ilford, Essex.

Mr. D. N. Riley has been appointed manager of the Rotherfield works, and **Mr. E. E. Beard** manager of the laminated and coil spring department of Samuel Fox & Co. Ltd., Stocksbridge, near Sheffield.

Mr. D. F. Ringe, formerly chief designer, has been appointed general manager of Vokes Limited, Guildford, Surrey. **Mr. K. D. Mulcaster** has been appointed to the position of chief designer.

Mr. H. L. Satchell, M.B.E., a director of BTH since 1949, has been appointed director of manufacture of the British Thomson-Houston Co. Ltd., Rugby, with effect from 1st October, 1957, in succession to **Mr. W. W. Vinsen,** who will retire at the end of this year.

Mr. R. K. Saunders has been appointed instrument sales manager of Ferranti Ltd., Hollinwood, Lancashire.

Mr. M. Seaman, having recently become director and general manager of British Oxygen Gases Ltd. (Equipment Division), has relinquished his appointment as director and general manager of British Oxygen Engineering Ltd. **Mr. R. J. Foster,** formerly general manager, has now been appointed director and general manager of British Oxygen Aro Equipment Ltd.

Mr. A. Neville Stack has been appointed deputy to **Mr. P. J. Sims, M.I.Mech.E., M.I.Mar.E.,** manager of the Marine and Industrial Section of A.C.V. Sales Ltd., 50 Page Street, London, S.W.1.

Mr. J. Russell Taylor, T.D., B.Sc., M.I.E.E., M.I.Mech.E., director of research and development of the Igranic Electric Co. Ltd., Bedford, will relinquish his departmental responsibilities as from January, 1958, to become consultant to the managing director of the company. **Mr. G. B. Harrold,** who has been working closely with Mr. Russell Taylor for some years, will become chief development engineer.

Mr. Charles K. Turner-Hughes, A.F.R.Ae.S., has been appointed chief sales executive of Simms Motor Units Ltd., Oak Lane, London, N.2.

Mr. R. L. Webster, chief personnel manager of Hoover Ltd., Perivale, Greenford, Middlesex, has been elected President of the Institute of Personnel Management.

Mr. C. B. Wright has been appointed technical sales manager of Davy and United Roll Foundry Ltd., in succession to **Mr. L. W. H. Ashton.**

Mr. K. B. Youngman, B.Sc.(Eng.), has joined Simms Motor Units Ltd., Oak Lane, E. Finchley, London, N.2, as engineer-in-charge of turbochargers and gas-turbine fuel equipment.

STATUS OF THE ENGINEERING PROFESSION

Some regulation must be introduced in the use of the description " engineer ", for it is essential to Britain's future that the status of the professional engineer must be maintained at a high level.

This was one point made by Dr. B. N. Cole of Birmingham University, addressing a Forum organized by the West Midlands Branch of the Engineers' Guild at the Birmingham College of Technology. The distinguished engineer, Sir William Stanier, who is President of the Engineers' Guild, pointed out that Britain had fallen behind other countries in the number of professional engineers being produced, and stressed that it was estimated that by 1970 this country would need double the present number.

Dr. Cole said the scope of engineering had increased beyond any expectations, with specialized groups for all kinds of subjects, and that it was hardly surprising that the very word " engineer " has become ambiguous in this country, serving impartially to describe a repairer of old radio sets of the designer of a nuclear power station.

" Life over the whole world ", he said, " has become coloured by the vast increases of scientific knowledge gained in the past few generations. Each country is making heavy demands upon its engineer. There is international competition for survival."

The high social status given to the engineer in Germany assisted and encouraged the remarkable technological progress in that country, particularly in post-war years.

Russia had made great strides in the training of professional engineers, mainly because of the teaching system.

The engineering teaching profession in Russia is made especially attractive by the obvious expedient of attaching high salaries, which even exceed corresponding ranges for industrial appointments.

Dr. Cole said that in Russia " something approaching half of the total intake of students of engineering are women".

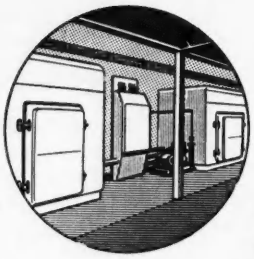
Suggesting that the description " engineer " should be regulated more carefully, he said—" The word profession connotes a high level of personal attainment, discipline, and responsibility."

Sir William Stanier summarized the steps that the Engineers' Guild is taking to promote the status and conditions of the professional engineer. It is proposed to establish a definition of the engineering profession and to bring about its acceptance by the Government, industry, and the public. A survey of salaries and conditions of service must be carried out.

There exists widespread ignorance of the responsibilities which the professional engineer carries for the well-being of humanity. If this continues it is likely to affect not only the status of the engineer, but also future recruitment to the profession, and in the long run affect adversely the prosperity of the nation.

Sir William commented—" The future is unlikely to be satisfactory for the profession unless the profession takes steps to make it so. It is no use our complaining of lack of public recognition of the responsibilities and achievements of the engineering profession, unless we are prepared ourselves to work for the replacement of ignorance and apathy by knowledge and respect.

" The Engineers' Guild has recently adopted a new and vigorous programme designed to meet the needs of professional engineers to-day. We believe that the execution of this programme will not only be of direct benefit to every professional engineer, but also of fundamental importance to the future of the profession itself."



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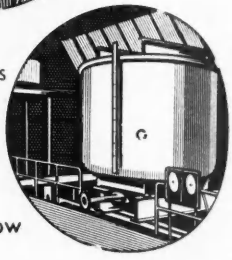

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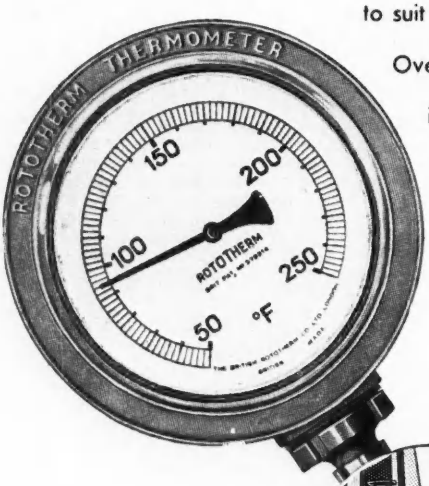

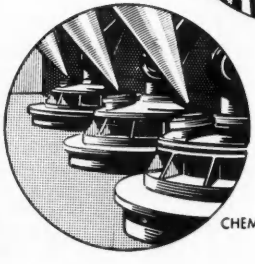

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BUSINESS NOTES

International Combustion (Holdings) Ltd. has acquired The Clayton Equipment Co. Ltd., of 138 Borough High Street, London, S.E.1, whose main products are diesel-electric locomotives, electric battery locomotives, electric trolley locomotives, also cement-making plant by the vertical kiln process. Mr. S. R. Devlin, the founder of the business, will continue as managing director.

Additional manufacturing capacity will enable the Clayton Equipment Co. Ltd., to expand its activities.

Fairey Air Surveys, a subsidiary of the Fairey Aviation Company, has won a contract to photograph 200,000 square miles of territory in Burma.

Valued at £200,000 it is believed to be the largest single contract ever to be signed between a government and a private company for aerial photography. Companies from Canada, France, Germany, Israel, Japan, the Netherlands, and the United States competed for this contract, which covers practically the whole of Burma.

Opening undeveloped areas of the world by air is becoming increasingly widespread. Apart from air survey, the other main uses for which aircraft can be used in this field are freighting and agriculture.

Winston Electronics Ltd., Shepperton, Middlesex, have been appointed sole United Kingdom agents for a number of industrial electronic control instruments manufactured by Beckman Instruments, G.m.b.H., Munich, Germany, and Beckman Instruments, Inc., Fullerton, California, U.S.A.

Permali Ltd., Bristol Road, Gloucester, announce that partial occupation of their new 180,000 sq ft factory has now released more space in the existing works to expand manufacture of P.T.F.E. (polytetrafluoroethylene) products. This material is sold under the registered name of Permaflon and, among its many properties, it completely resists most chemicals between a working temperature range of — 80°C to 250°C. It is available in sheet, block, cylinder, rod, and other forms, including dispersion coatings.

Conference on Technology of Engineering Manufacture. The Institution of Mechanical Engineers is arranging a Conference on Technology of Engineering Manufacture, which will be held in London from 25th–27th March, 1958. The Conference has been planned on an international scale, as many of the authors taking part are from the United States and from Europe. Some 60 papers will be presented and discussed at the various Sessions.

The Radio Industry Council announces that the 25th National Radio and Television Exhibition will be held at Earls Court, London, from 27th August to 6th September, 1958, with a pre-view on Tuesday, 26th August.

Mitchell Engineering Ltd., 1 Bedford Square, London, W.C.1, announce that they and their U.S. Associates, AMF Atomics Inc., have withdrawn their offer to construct a 15-MW boiling-water reactor power plant with a urania-thoria core for RWE (Rheinisch-Westfalische Elektrizitätswerk), one of West Germany's power producing organizations.

The reason for this move was that AMF Atomics had been unable to come to agreed financial terms with the U.S. Atomic Energy Commission with regard to the development of the urania-thoria core.

Because of this, AMF-MEL had to offer a substitute core to RWE. This core would have been made up of uranium oxide stainless-steel clad fuel elements with an average 2% enrichment. If this offer had been accepted by RWE the reactor was guaranteed to go critical within the original time and price schedules and to give the required net electrical output. Preliminary orders had been planned with German industry for the reactor vessel, heat exchangers, and building of the whole containment structure.

RWE have asked that the consortium of AMF/MEL/Siemens-Schuckertwerke submit an entirely new offer based on the new core proposals, and lodge this as soon as possible.

Air Products (Great Britain) Ltd., a new company, has been formed by Air Products, Inc., of Allentown, Pa., and the Butterley Co. Ltd.

The new organization will be primarily involved in the design, manufacture, installation, and operation of oxygen plants and other low-temperature equipment for the British Commonwealth and European markets, and will also produce and sell industrial gases, sewage-treatment equipment, and textile-cleaning equipment.

Modern manufacturing facilities and experienced personnel of Hughes and Lancaster Ltd., a subsidiary of the Butterley Company, form the nucleus of Air Products (G.B.) Ltd. This manufacturing operation is located in Acrefair, North Wales.

Two oxygen plants, each exceeding 200 tons per day capacity, are currently under construction. One is being built for Stewarts and Lloyds Ltd. at Corby, and the other for Imperial Chemical Industries, at Billingham.

Other smaller plants are being erected for military and commercial applications.

Dexter Baker, former general sales manager of Air Products, Inc., has been named managing director of the new organization and will be responsible for all phases of marketing, engineering, manufacturing and operations. Administrative offices are located in London.

The Hoffmann Manufacturing Co. Ltd., Chelmsford, Essex, announce that their Newcastle office and stockroom have recently been removed to larger premises at Rutherford Street (off Westgate Road). Tel.: Newcastle 23041/2. Mr. W. N. Mills is area manager.

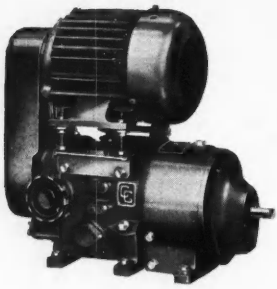
George Cohen Sons & Co. Ltd., 600 Wood Lane, London, W.6, have been appointed sole agents in Great Britain for the Dorst Automatic Press for powder-metallurgical applications.

Kerry's (Great Britain) Ltd., Warton Road, London, E.15, have acquired Oldfield & Schofield Ltd., Boothtown, Halifax, manufacturers of machine tools. Mr. Clifford Schofield will continue in office as director and general manager. This addition follows closely on the establishment of Kerry's (Ultrasonics) Ltd., Harold Hill, Essex, formed to co-ordinate the Group's activities in the field of ultrasonic and electronic equipment for industry.

John I. Thorneycroft & Co. Ltd., Woolston Works, Southampton, announce that their extensive facilities are now available to other industrial and commercial concerns. The newly formed Engineering Service Department is in the position to assist in supplying a great variety of engineering products, including boilers, castings, fabricated steelwork, tanks and pressure vessels, turbine machinery, electrical products and repairs, etc.

The British Thomson-Houston Company's new turbo-alternator factory, the largest in Europe, was officially opened by The Duke of Gloucester on October 24th. It was built at Larne, Co. Antrim, Northern Ireland, at a cost of over £8,000,000. Over 1,500 people are already employed, and the complete scheme will employ more than 3,000.

Lord Chandos, chairman of B.T.H., who presided, said that the project was designed to produce turbo-alternators for generating electric power of 30,000 kW and upwards. He estimated that demand for electric power in this country will roughly double every 10 years.



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Ransome & Marles Bearing Company Ltd., Newark-on-Trent, have acquired the exclusive British rights for the manufacture and sale of Thomson linear ball bushings, which are widely used in America.

The Hoffmann Manufacturing Co. Ltd., Chelmsford, Essex, have opened a new stockroom at 127 Bath Road, Slough, where an extensive range of their ball and roller bearings is carried.

The Plant Maintenance & Engineering Show and Conference will take place in Chicago from January 27 to 30. The Exhibition will be held at the International Amphitheatre, and conference sessions will be held both at the Amphitheatre and the Palmer House. Sixty-six speakers, representing a very wide range of industries, will address the 25 sessions of the conference.

Southern Areas Electric Corporation Ltd., 28 Queen Anne's Gate, London, S.W.1, announce that the production unit of New Day Electrical Accessories Ltd. has now been fully transferred and the company has been completely integrated with New Day Electric Ltd., Chalford, Glos.

Bound Brook Bearings Ltd. has opened a new office and stock depot at 38 King Street West, Manchester 3. Telephone : DEAnsgate 6431.

F. Perkins Ltd., Peterborough, has created a New Products Division to develop and introduce certain new products into the organization. Mr. D. F. W. McNair, B.A., export sales manager, has been appointed general manager of the new division, with Mr. G. E. Smith, personal assistant to the deputy managing director, as deputy general manager. Mr. J. M. Collins, general manager of Perkins Diesel (Overseas) Pty. Ltd., Dandenong, Australia, will succeed Mr. McNair as export sales manager. **Mr. D. McSweeney** will be the new general manager of the Australian company.

Edwin Cooper & Co. Ltd., 43 Grosvenor Street, London, W.1, a member of the Wakefield Group of Companies, will market certain chemical additives for lubricating oils, which will now be made available by Wakefield to the outside market, as well as other chemical products not necessarily connected with lubricants, which the Wakefield Group intend to manufacture.

British Oxygen Gases Ltd., Spencer House, St. James's Place, London, S.W.1, announce the building of a new oxygen compressing station at Durranhill Industrial Estate, Carlisle. Site work has just commenced, and the station is expected to be completed in the spring of next year.

British Chrome & Chemicals Limited, Eaglescliffe, Nr. Stockton-on-Tees, have placed an order with The Power-Gas Corporation Limited for a new contact plant with an output of 100 tons per day H_2SO_4 in the form of 95% and 70% strengths. Elemental sulphur will be the raw material. This plant will be built to the design of Chemiebau Dr. A. Zieren G.m.b.H., who co-operate with The Power-Gas Corporation for the installation of sulphuric acid plants in this country and abroad.

Rolls Royce Ltd., Derby, will take over in the near future the 230,000 sq ft factory occupied by Kelvinator Ltd., to cope with growing production demands. Kelvinator Ltd. will transfer its complete operation to a new factory at Bromborough, near Liverpool, which is nearing completion.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 2 Park Street, London, W.1)

Built-on coolant pumps for internal combustion engines (nominal output 1750–17,500 gph at 30 ft maximum head) B S. 2896:1957 is designed to secure a measure of standardization of dimensions of components of internal combustion engines. The standard specifies a range of 4 suction and discharge bore sizes, i e., 1½, 2, 3, and 4 in., and certain dimensions for suction and discharge flanges, suction and discharge stubs, the pump shaft in the immediate vicinity of the coolant seal, driving splines, the mounting flange, and spigot and housing for coolant seals.

It is envisaged that pumps embodying these features will be suitable for use on future industrial, locomotive, or marine engines in the power range 150–2000 hp. The standard, which is illustrated, contains an appendix which sets forth a number of useful recommendations on pump design. Price 4*s.* 6*d.*

Troughed belt conveyors. B.S. 2890:1957 provides for the comprehensive standardization of all major components, thus making for easier interchangeability and replacement of parts.

The main sections of this 40-page standard specify important dimensions and recommended limiting dimensions for the principal mechanical parts, e.g., idler sets, pulleys, and shafts. There is also much information on general mechanical requirements. Certain conditions are specified with regard to the provision of take-up devices, skirt plates, trippers (where applicable), and safety devices.

Specifically, the standard applies to ". . . troughed belt conveyors incorporating rubber and cotton fabric belting manufactured to B.S. 490 for handling materials in bulk, within the range of belt widths from 14 to 60 in."

Inevitably, the installation in a factory of such a conveyor could present many pitfalls, not least because of the many safety precautions which a conveyor must incorporate. Here, two of the standard's appendices will prove

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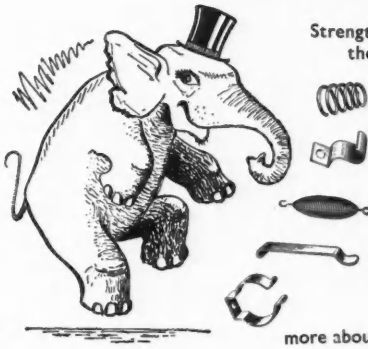

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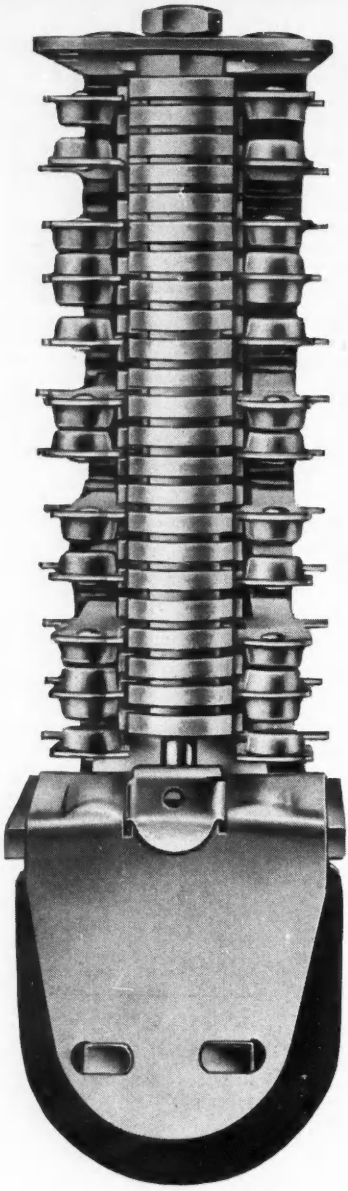

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of assistance. One lists 28 items of information which the purchaser should supply to the manufacturer; the other lists 18 items of information which the manufacturer should supply to the purchaser. Another appendix lists the titles of eight statutory provisions affecting conveyors. Yet another provides a "quick reference" list of British Standards with which a conveyor should comply—the information being tabulated under "materials", "mechanical details", and "electrical details".

Another feature of the standard which will help to avoid misunderstanding between buyer and seller is its list of 20 definitions, e.g., of the five items which constitute "driving gear"—each of which is defined in precise terms.

The standard does not apply to feeder belts and underground mining conveyors, nor does it apply to the handling of materials of which the liquid content is such that the material does not behave as a solid. Price 8*s*. 6*d*.

Hand Hammers. B.S. 876:1957. Here, the simple hammer is the subject of a 40-page revision of B.S. 876 "Hand Hammers", which was first published in 1939 and was revised ten years later. The fourteen types of hammer for which quality and dimensions are specified range from the delicate 3½-oz. pin hammer, through engineers' and joiners' hammers, to railway-track keying hammers, stonebreakers' hammers, and 16-lb sledge hammers.

The new standard emphasises safety based on *quality* of materials, to which are applied new forms of test whose criterion is the use of the tool. They include, for example, one three-stage test designed to test to the utmost the basic soundness of both the head and the handle. Another change is that the hammer heads are now required to be made from steel in the "En" series—in place of steel conforming to the analysis specified in previous editions.

Adherence to the standard will ensure the production of a hammer of high quality, i.e., constructed of good materials, as safe in use as a hammer reasonably can be, and realistically designed as regards shape, weight, and balance. With a good deal of competition between exporting countries for the "hand-tool trade", hammers to B.S. 876 should certainly prove worthy challengers in this lucrative market. Price 8*s*. 6*d*.

CONTRACTS

Metropolitan-Vickers Electrical Export Co. Ltd. has received an important contract for power-generating equipment from the British Columbia Electric Co. Ltd., Vancouver, Canada. The order is for four 150-MW steam-turbine generator sets, together with condensers and steam auxiliary equipment. Two further generating sets, of the same capacity and with similar condensers and associated equipment, will be ordered at a later date, bringing the total value of the contract to 30 million dollars.

This is the largest dollar order for steam-turbine generator plant of its kind ever placed in this country. Dr. T. Ingledow, vice-president and executive engineer of the British Columbia Electric Company, has negotiated the contract, at the same time appointing Messrs. Balfour, Beatty as consultants. It is significant that an order of such magnitude was placed so soon after the meeting called by the Prime Minister of Canada for the discussion by Commonwealth Ministers of the furtherance of trade relations between the United Kingdom and Canada.

The first two generating sets will be commissioned in January and August, 1961.

The British Thomson-Houston Export Co. Ltd. and International Combustion (Export) Ltd. have received from the Water and Electric Energy Board of the Ministry of Industry and Commerce, Argentina, a contract valued at over £30-million for the new 600,000-kW Greater Buenos Aires Power Station.

The plant to be supplied includes five 120,000-kW turbo-alternators, boilers and fuel-handling equipment, transformers, switchgear, motors, and control gear.

In association with the BTH-ICL partnership, an Argentinian consortium of civil engineering contractors will carry out the civil works.

The consulting engineers engaged by the BTH-ICL partnership are Merz and McLellan (plant layout and technical co-ordination) and Sir William Halcrow and Partners (civil work).

Higgs and Hill Ltd., James Burness and Sons Ltd., The Brush Group Ltd., and Brian Colquhoun and Partners have formed a consortium to build a shipyard in Cuba and 25 ships for carrying sugar, iron ore, other bulk commodities, and general cargo. These companies have signed a declaration of common purpose with the Banco de Desarollo Económico y Social (BANDES) with the co-operation of the Banco Cubano del Comercio Exterior. The total cost has been estimated at £30 million.

The Brush Group Ltd. states "The Brush Group is part of the consortium and if agreement is reached on details we expect substantial orders. No details have yet been settled, but it appears that the main part of the contract affecting the Brush Group will probably be to supply 25 sets of main propulsion machinery and 25 sets of engine room auxiliary machinery."

The size of the ships is not yet finally decided, but they will probably be about 5000 tons deadweight, with propulsion machinery of about 4000 hp.

The Group may also receive orders for a large quantity of electrical equipment and possibly an order for a power station for the shipyard.

As far as can be ascertained at the moment, the Brush Group's part of the contract will be worth between £5 and £6 million.

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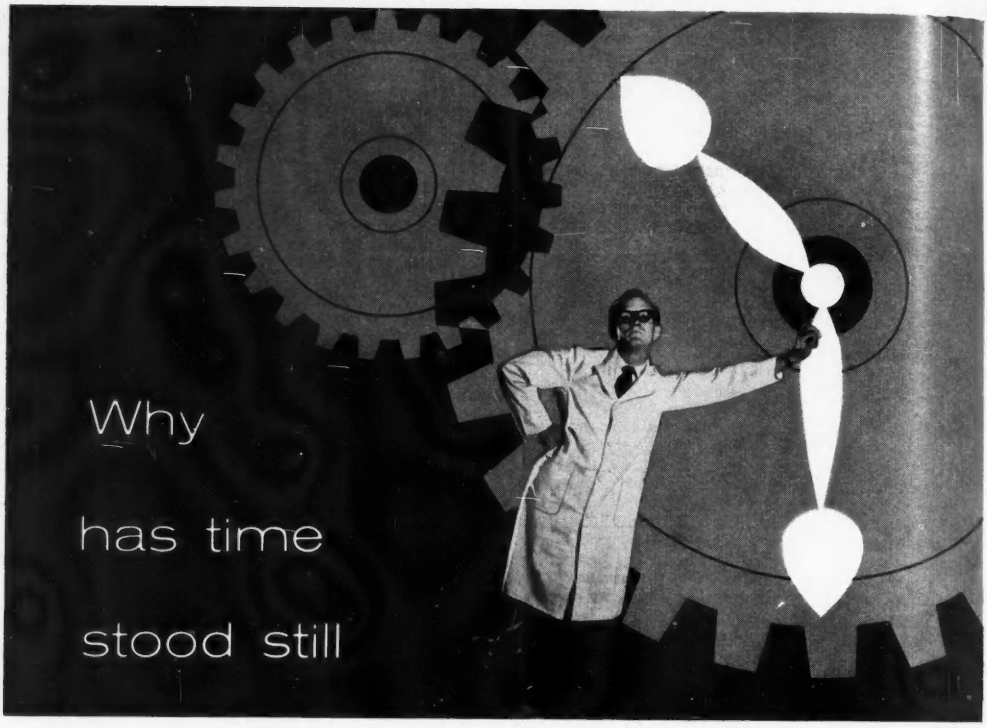

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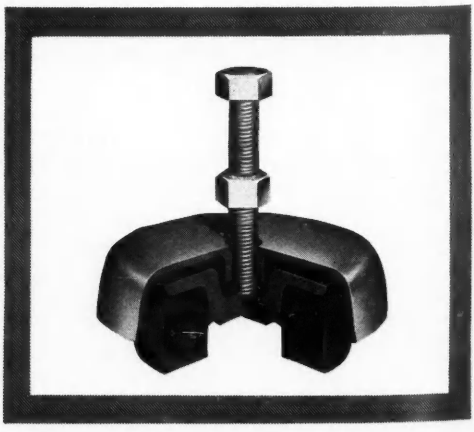

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BOOKS RECEIVED

Factory Organization and Management. Seventh Edition, 1957. By T. H. Burnham, B.Sc. (Hons.), B.Com., F.I.I.A., M.I.Mar.E., A.M.I.Mech.E., A.M.I.E.E., A.M.I.Prod.E., and D.H. Bramley, M.I.Mech.E., M.I.Prod. E. 408 pp., 94 illustrations. Publishers : Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price : 25/–.

Under modern industrial conditions, management has developed into a calling involving a special technique and necessitating a systematic scheme of education. Successful management depends chiefly on the personal qualities of the manager himself and, as management is such a vital factor in industry, it is not surprising that it has an increasing appeal to highly trained engineering students.

The aim of this book, then, is to direct attention to the necessity for criteria of industrial efficiency and optimum values. In this revised edition, some of the basic ideas about management and organization have been rewritten and amplified, making it a comprehensive study of the subject, covering the requirements of the new syllabuses on Factory Management and Organization, developed in the Ministry of Education White Paper on Education and Training for Management.

There can be no doubt that this excellent book (No. II in the "Engineering Economic Series") is of great value to students of mechanical and production engineering and to all those requiring a systematic preparation for industrial responsibility.

Generation, Transmission and Utilization of Electrical Power. Fourth Edition, 1957. By A. T. Starr, M.A., Ph.D., M.I.E.E. 540 pp., 431 illustrations. Publishers : Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price : 27/6.

Specially written to meet the requirements of the Electrical Power syllabus of the Engineering Degree, this excellent book covers a very wide field, though it still contrives to deal with each branch of the subject in considerable detail. Comprehensive details are given of steam-turbine and hydroelectric methods of generating electrical power, while useful particulars of station design, operating costs, and an account of the work of the Central Electricity Authority are included.

In this revised edition, a number of amendments have been made, and additional material has been incorporated, including an appendix on nuclear energy and an outline of the Calder Hall Station.

The Rolling of Strip, Sheet and Plate. By Eustace C. Larke, A.M.I.Mech.E., A.I.M. 416 pp., 205 illustrations. Publishers : Chapman and Hall Ltd., 37 Essex Street, London, W.C.2. Price : 63/–.

When correctly applied to the design and operation of rolling plant, sound scientific principles increase productive efficiency, decrease the risk of expensive mechanical breakdown of plant, and enhance the shape and dimensional qualities of products. This authoritative book, which is specifically intended to meet the needs and to stimulate the interest of rolling-mill managers, their technical and practical assistants, engineers concerned with plant design and operation, and metallurgical and engineering students, discusses virtually all aspects of the subject. Thus, for example, full details are given of roll cambers, the causes and control of gauge variation, factors affecting rolling loads, the design of rolling schedules to ensure maximum production, the calculation of the roll separating forces developed during hot and cold rolling and how the associated energy consumed and the power developed can be computed. A number of fully worked out numerical examples is included.

In addition, reasonably comprehensive descriptions with illustrations are given of modern rolling plant, including such types as Sendzimir and planetary mills, while a chapter is included on the productive capacity of strip mills as affected by such factors as handling time, rolling speed, product weight, and coil length.

As Dr. Maurice Cook says in his Foreword, "Mr. Larke has performed a most useful service to all who are interested in the rolling of metals. But he has done more than this and has written about the subject from his own intimate and extensive knowledge of it. . . ."

Applied Analysis. By Cornelius Lanczos. 560 pp., 45 illustrations. Publishers : Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price : 55/–.

For many years, Professor Lanczos, who was at one time a collaborator with Einstein, has been engaged in studying those fields of mathematical analysis which are the primary concern of engineers and physicists. In this connection, there has been a gradual separation of pure and applied mathematics, until now "pure" analysts pursue their ideas in a world of purely theoretical constructions, while "numerical" analysts translate the processes of analysis into machine operations.

In actual fact, there is a large area between these two extremes which is devoted to the analysis of finite algorithms, the objective being the analysis and design of finite processes approximating the solution of an analytical problem. The design of procedures which will effectively minimize the error in a small number of steps and which will estimate the error with sufficient accuracy is not only of practical interest but also of scientific interest. This book is largely devoted to such problems, and is essentially a philosophical and strictly theoretical approach to mathematical methods used in the solution of physical and engineering problems.

It successfully fulfils its aims to develop an appreciation of, and an ability to use, a few fundamental but powerful mathematical principles and, as such, will appeal not only to teachers and post-graduate students of physics, engineering, and mathematics, but also to all those engineers, physicists, and applied mathematicians engaged in research and development, who will find that they continuously encounter in their work the topics considered in this book.

LATEST INDUSTRIAL LITERATURE

1. Stainless-Steel Clad Rolls. A newly patented process for the external cladding of rolls, shafts, tubes, and drums with stainless steel and other hard-wearing and corrosion-resistant materials is outlined in an illustrated leaflet. It is claimed that the process described overcomes the difficulties encountered with other methods of roll cladding, and that its application will benefit a wide range of industries, including textiles, plastics, paper, printing, fine chemicals, mechanical handling, etc. Rolls and shafts protected by this method of cladding are suitable for working in temperatures from —40°C to 300°C, and, although stainless steel is the most usual cladding metal, the process can be applied with equal success to similar materials.

2. Machine Tools. In a well-designed and illustrated 44-page brochure, specifications are given of a range of grinding machines, milling machines, chucking machines, multi-spindle automatics, etc. Details are also included of a new vertical-spindle chucking lathe, constructed from sheet steel. An interesting feature of this machine is the use of two hydraulically operated tool-slides which can be swivelled from below horizontal to beyond the vertical position, enabling the lathe, apart from normal turning, to be able to machine simultaneously two internal tapers, two external tapers, or an internal and external taper. Although primarily intended for repetition work, the machine is so easily set up that it can be conveniently used for small quantities.

In addition, a new design of horizontal boring and milling machine is described, incorporating a unique method for mounting the spindle headstock. The vertical headstock guides consist of two substantial precisely machined round columns secured to the bed by a vertical column and top cap. Both the round columns guide the spindle headstock concentrically between the columns, and the rear extension of the boring spindle is carried in the support column, thus preventing the entire spindle headstock from deflecting from the centre-line under tranverse pressure.

3. Portable Pneumatic Tools. Details of a complete range of portable pneumatic tools are contained in an illustrated loose-leaf folder. Over 100 different models are described, including drills of various types, screwdrivers, nut-runners, spanners, tappers, grinders, and special-purpose tools. A section is also devoted to accessories and airline equipment, including rotary files, sanding and polishing pads, cleaning outfits, hoses, and connectors.

4. Conveyor and Elevator Belting. Useful data on a wide range of conveyor and elevator belting are contained in a neatly produced 14-page booklet, and include brief descriptions of methods of working out calculations for conveyor belting.

The belting described is in certain cases designed to resist temperatures up to 392°F, extra-oily substances, and extremely abrasive materials. Furthermore, as it is both tasteless and odourless, it is especially suitable for food-handling applications.

5. Meehanite Castings. Brief descriptions of a variety of uses for Meehanite castings, produced by a leading British manufacturer in a range from 1 lb to 20 tons, are given in an illustrated 8-page brochure. Details are included of wear-resistant castings, of castings able to withstand severe underwater shocks and the corrosive action of seawater, of heat-resistant castings, etc.

A system of quality control ensures that all these castings are produced to the required standard and for the purpose intended, many grades being available to meet various requirements.

6. Diecasting and Basin-Tilting Crucible Furnaces. Technical information on a new electric diecasting furnace and an oil-fired basin-tilting crucible furnace, is given in two comprehensive illustrated booklets.

Combining the advantages of crucible melting with the benefit of electric heating, the electrically heated diecasting furnace has a capacity of 300 lb (aluminium) for maintaining aluminium and aluminium alloys. By fitting an automatic time-switch, the furnace can be ready for instant use, thus assisting in reducing the cost involved in starting up the plant before normal working time. The basin-tilting furnace is an aluminium bulk melting furnace for feeding maintaining furnaces. It has a capacity of 380 lb (aluminium) and uses a spouted basin-shaped crucible to facilitate charging ingot or scrap. A special feature of this furnace is the built-in tilting mechanism, giving a smooth lip pour with finger-tip control.

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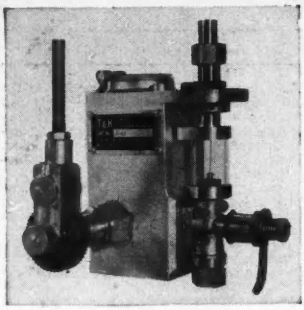

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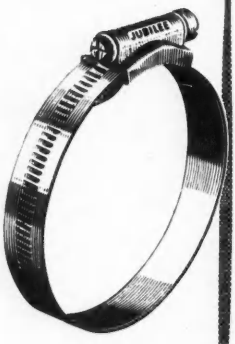

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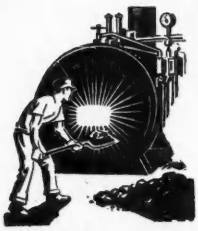

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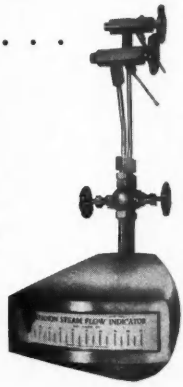

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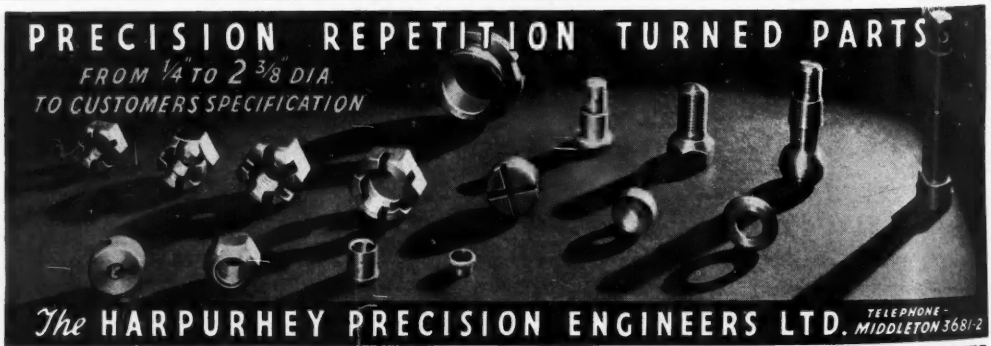

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